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A Greener Future using Machine Learning: Transforming the Environment in Big Cities

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ABSTRACT:
One of the main elements that influences daily life is the environment. Especially in big cities, it leaves an important mark on the quality of life of its inhabitants, a quality that concerns many aspects such as their health, the quality of the air they breathe, the temperatures generated by the city's architecture, the size of green spaces, the noise level, etc. Big cities must achieve a balance between all these factors that influence the lives of their inhabitants. A lot of data and information about everything that can influence the quality of life is collected and analyzed. One of the elements that can help transform big cities by improving the quality of life, optimizing resources and reducing environmental impact for a smarter and greener future is Machine Learning (ML). ML is about developing algorithms that allow computers to learn from data and make predictions or decisions without explicit programming. The purpose of this paper is to highlight the role that ML can play in improving the quality of life in big cities and the contribution it can make to their sustainable development. The sections of the paper aim to identify and describe the aspects that concern the environment in big cities, the specific aspects of ML as well as the optimization that ML can bring through its use. Finally, the use of ML for a city-related data set is exemplified.

Keywords: environment, machine learning, big cities, data mining

1. Introduction

A greener and more sustainable future is essential to the well-being of our planet and overall quality of life, requiring global efforts to combat climate change, pollution and biodiversity loss. Around the world, governments, companies, businesses and individuals are increasingly adopting more sustainable approaches, such as using renewable energy sources, reducing waste and protecting ecosystems. Technological and technological advances, such as electric vehicles and carbon capture, help, too, in reducing greenhouse gas emissions. However, true sustainability requires strong policies, international cooperation and a commitment to medium to long-term goals as well as the implementation of these commitments to the greatest extent possible.
In the European Union, the Green Deal serves as a general commitment for the countries of the European Union and not only, for Europe to become the first climate-neutral continent by 2050 (Mogos et al., 2021; Lau et al. 2023). This ambitious plan, which aims, among other things, to reduce carbon emissions, promote energy efficiency and support sustainable industries. The EU is also investing in greener transport, circular economy initiatives and biodiversity conservation to ensure future generations a healthier, cleaner

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and more sustainable environment (Mogos et al.,2023). Stricter environmental regulations and financial incentives encourage companies and citizens to adopt environmentally friendly practices, making sustainability an essential part of economic growth (Bodislav et al., 2019).

A greener future will only be possible if individuals and institutions work together to adopt sustainable lifestyles and policies. Citizens can contribute by reducing their carbon footprint, choosing green products and sponsoring green initiatives. Governments and businesses should continue to invest in innovation and renewable energy, while imposing environmental laws. Through collective action, the world and the European Union can create a future in which economic prosperity and environmental protection go hand-in-hand, ensuring a cleaner and healthier planet for future generations to come from a greener future. of adopting sustainable solutions that reduce pollution and improve the quality of life of residents. Extending green spaces, planting trees and developing infrastructure for alternative transport, such as bike lanes and electric public transport, are essential for reducing carbon emissions. Similarly, smart roofs, which use renewable energy sources and efficient water and energy saving systems, can transform cities into more environmentally friendly spaces (Mogos et al., 2024(1)).

A "large city" is, in general, a city with a significant population and extensive urban infrastructure (Sarbu et al., 2021). The exact definition varies depending on the context and country in which the term is used. Common criteria for a large city: population (a city with over 500,000 inhabitants), surface area and infrastructure (large cities have extensive transport networks such as subways, trams, highways, airports), the existence of a few commercial areas, residential and industrial areas development, economic and administrative importance (these cities are the economic, cultural or political centers of a region or city), they host the headquarters of large companies, universities and important institutions.

In addition, involving communities and promoting a sustainable lifestyle plays an essential role in building a greener future. Recycling, using clean energy and reducing excessive resource consumption are measures that every citizen can adopt. Local authorities should foster environmentally friendly initiatives through efficient urban planning policies, funding environmental projects and educating the population about the benefits of a sustainable city. Through collaboration and innovation, big cities can become greener, healthier and more enjoyable for future generations. Lucrari precum (Alberti et al., 2019; Oquendo-Di Cosola et al., 2022; Jiahao et al., 2024; Molitor &White, 2024; Zhang et al., 2025;)

The research paper is structured in 3 parts. In the first part, the environmental problems specific to large cities and urban agglomerations are identified, as well as the projects and actions taken to combat them at the European Union level. In the second part, the specific aspects of Machine Learning are described, mentioning for each category specific algorithms that can help in solving the various problems specific to large cities. In the third part, a correlation is presented between environmental problems often encountered in large cities and the possible solutions that Machine Learning can offer to achieve a greener and more sustainable future. At the end of the article, an example of the use of Machine Learning for grouping large cities in Italy using data mining algorithms is presented.

The research questions to which this paper tries to provide answers are:

1. What are the environmental problems specific to large cities and what actions have been taken within the European Union?
2. What are the specific aspects of Machine Learning and how can it offer solutions to the challenges specific to large cities. and urban agglomerations?
3. What is the evolution of the large cities in Italy from an environmental point of view, namely Italy municipal waste generated (domestic and commercial).
In the following sections, an answer will be provided for each of the questions mentioned above.

2. Environment problems for big cities and proposed solution in European Union

Large cities around the world are increasingly facing major environmental challenges and problems due to rapid urbanization and high population densities. The important problem is air pollution, caused by vehicle emissions, industrial activities and construction dust. High concentration of pollutants, such as carbon monoxide and particulate matter, lead to respiratory diseases, poor visibility and overall quality of life decreased. Cities such as Beijing, Delhi and Los Angeles frequently struggle with smog, which presents serious health risks to residents.
The other issue of major interest is waste management. Large cities generate huge amounts of garbage daily, including plastic waste, electronic waste and organic waste. Without efficient recycling programs and waste disposal infrastructure, garbage pits fill up quickly, polluting soil and water sources throughout the area (Alpopi et al., 2022). Many cities face an ongoing struggle with illegal dumping, which contributes greatly to environmental degradation and the public health problems it entails.
Water pollution is also a major concern in urban areas. Industrial effluents, wastewater discharges and chemical discharges contaminate rivers, lakes and groundwater sources. This pollution not only damages aquatic ecosystems, but also reduces the availability of clean drinking water for residents. In some cities, water scarcity is exacerbated even more by inefficient water management and climate change, leading to droughts and water shortages.
Notwithstanding the above, defrosting and loss of green spaces contribute to rising temperatures and increasing levels of carbon dioxide. As cities expand, natural habitats are dispersed to make way for fences, roads and other infrastructure. Loss of forests and parks reduces biodiversity, increases urban heat island effects and worsens air quality. To combat this, cities should invest in implementing strategies and policies regarding sustainable urban planning, green infrastructure and policies that prioritize environmental protection.
EU projects and initiatives reflect the growing degree of awareness of environmental challenges in the urban environment and the need for collaborative efforts to create greener and more sustainable cities. Many of these projects align with broader EU goals, such as the European Green Deal, which also proposes to make Europe the first climate-neutral continent by 2050 (Mogos et al., 2023).
The following are the main environmental problems facing large cities in the European Union (EU) as well as related projects and initiatives aimed at combating them:
1. Air pollution - high levels of vehicle emissions and industrial activity contribute to poor air quality in many European cities and beyond, leading to respiratory diseases, heart

disease and premature deaths. The incidence of these diseases in populations is increasing year by year. One of the measures taken within the EU to combat this problem is the implementation of the CLEAN AIR for Europe (CAFE) project. This is an initiative focused on improving air quality by setting air quality standards and providing recommendations for cities to reduce pollution levels.

2. Traffic congestion and urban mobility - traffic congestion contributes to greater pollution from several points of view. The air quality is affected, noise levels are affected as well as the loss of the most important resource, time. One of the solutions adopted within the EU to combat this problem was the initiation of the CIVITAS project. This project supports cities in testing and implementing innovative mobility solutions, including cleaner public transport and bike sharing schemes, to reduce congestion and promote sustainable urban mobility.

3. Climate change and extreme weather events - many cities in the EU are vulnerable to floods, heat waves and extreme weather events due to climate change, which are occurring more and more frequently every year. One solution to combat this phenomenon is the launch of the Covenant of Mayors for Climate and Energy project. This project involved a growing number of cities committing to reducing their carbon footprint and adapting to climate change by adopting climate action plans.

4. Waste management - large urban populations generate massive amounts of waste, often leading to landfills, pollution and waste incineration. One solution to this problem was the proposal of a Circular Economy Action Plan. This plan encourages cities to move from a linear to a circular economy, with initiatives that promote recycling, reuse and waste reduction.

5. Water scarcity and pollution - in many situations, there is excessive use of water resources and pollution of freshwater sources in industrial, agricultural and domestic activities. One step to remedy this problem was the initiation of the draft Water Framework Directive. This framework directive requires EU countries to protect and improve the quality of water resources by reducing pollution, managing water use and restoring water ecosystems.

6. Noise pollution - traffic, construction and industrial activities cause high levels of noise pollution in urban areas, leading to health problems such as stress, sleep disorders and hearing loss. The European Noise Directive is a draft that requires EU cities to assess and manage noise pollution, especially from transport and industry, by creating noise maps and action plans.

7. Urban heat island effect - dense cities with little green space absorb and retain heat, causing temperatures to rise, which exacerbates energy consumption for cooling and affects health. The EU Green Urban Infrastructure initiative aims to promote and create green roofs, parks and tree-lined streets to reduce the heat island effect.

8. Biodiversity loss - urban sprawl and habitat destruction often lead to irreversible biodiversity loss and ecosystem fragmentation. EU project The Life+ Nature and Biodiversity Programme aims to support conservation projects that aim to protect species and habitats in EU cities, including the creation of green corridors and the restoration of urban ecosystems.

9. Energy consumption - cities consume large amounts of energy, largely from non-renewable sources, thus contributing to climate change. An EU-level initiative is the Smart

Cities and Communities project. This project is a funding programme that helps cities develop smart grids, energy-efficient buildings and renewable energy solutions to reduce energy consumption and carbon emissions.
10. Floods - these are becoming more frequent and severe due to climate change, urban development and inadequate drainage systems. The EU Floods Directive aims to encourage EU cities to assess flood risks, identify and implement flood management strategies, and create flood risk maps to better prepare for and mitigate the often catastrophic effects of floods.
11. Plastic waste - high levels of plastic waste, especially single-use plastic, end up in many places, such as landfills, oceans and urban environments, causing a high level of pollution. The EU Plastics Strategy is an initiative that aims to reduce plastic waste in Europe, focusing on eliminating single-use plastics, promoting recycling and encouraging sustainable packaging practices.
12. Sustainable urban development - urban sprawl and poorly planned development can lead to environmental degradation, loss of green space and inefficient use of resources. The Urban Agenda for the EU is an initiative that promotes sustainable urban development through better urban planning, reducing pollution and integrating green spaces into urban design.
13. Wastewater treatment and management - many cities face challenges in treating and managing wastewater, which leads to water pollution in the region and health hazards. The Urban Wastewater Treatment Directive ensures that wastewater from cities is properly treated before being released into the environment, thus improving water quality and public health.
14. Land degradation and soil erosion - urban sprawl, industrial activities and poorly managed agricultural practices can lead to land degradation and soil erosion. The Land Degradation Neutrality Targeting Programme encourages cities to adopt land management strategies that restore ecosystems and prevent soil erosion, particularly in areas at high risk of degradation and erosion.
15. Social inequality and environmental justice - marginalized communities often face disproportionate environmental hazards, such as poor air quality, lack of green spaces and exposure to waste and pollution. The Just Transition Mechanism is a European initiative that aims to ensure that the transition to a green economy is fair, inclusive and addresses the needs of disadvantaged groups in cities, ensuring equal access to environmental benefits.
In this section it is offered the answer to the first research question, namely "1. What are the environmental problems specific to large cities and what actions have been taken within the European Union?"

3. Machine Learning

Machine learning (ML) is a field of artificial intelligence (AI) that allows computers to learn from data and improve their performance without explicit programming. Instead of following rigid, predefined instructions, ML systems analyze patterns in data and make predictions or decisions based on that information. This adaptability makes ML useful in a variety of applications, such as image recognition, fraud detection, language translation, and personalized recommendations. As the availability of large data sets and computing power increases, ML continues to transform industries by automating tasks and improving decision-making.

At the heart of ML are algorithms that process and interpret data, learning from previous examples to generate accurate results. These algorithms fall into different categories, including supervised learning, unsupervised learning, and reinforcement learning. Supervised learning relies on labeled data to train models, such as predicting house prices based on historical sales data. Unsupervised learning, on the other hand, identifies patterns in unlabeled data, helping with tasks like customer segmentation. Reinforcement learning focuses on decision-making, where an agent learns by interacting with an environment and receiving rewards or penalties for its actions (James et al., 2013; Goodfellow et al., 2016; Géron, 2019)

Machine learning is widely used in fields ranging from healthcare and finance to self-driving cars and robotics. In healthcare, ML helps diagnose diseases and personalize treatments by analyzing medical records. In finance, it detects fraudulent transactions and optimizes investment strategies. The development of deep learning, a subset of ML inspired by the neural networks of the human brain, has even more advanced capabilities in areas like natural language processing and autonomous systems. As technology evolves, ML continues to drive innovation, improving efficiency and accuracy in many aspects of everyday life.

ML algorithms can be categorized into three main types: supervised learning, unsupervised learning, and reinforcement learning. Each type has different approaches and applications, depending on the nature of the data and the problem being solved.

- Supervised learning: In this type, models are trained on labeled data, meaning that the input is associated with the correct output. The algorithm learns from past examples to make future predictions. Examples: linear regression (for example, it can involve estimating house prices based on factors such as size and location), logistic regression (for example, it can involve classifying emails as spam or not spam), Support Vector Machines (SVM) (for example, it involves identifying handwritten digits), neural networks (for image recognition and speech processing).
- Unsupervised learning: This type involves training models on unlabeled data, where the algorithm finds hidden patterns or structures without predefined categories. Examples: K-Means Clustering (segmenting customers based on shopping behavior), hierarchical clustering (organizing documents into groups based on topics), principal component analysis (PCA) (reducing dimensions in large data sets), auto-encoders (identifying anomalies in network traffic).
- Reinforcement learning: In this type, an agent learns by interacting with an environment and taking actions to maximize rewards over time. This approach is useful for decision-making tasks. Examples: Q-Learning (trains artificial intelligence to play video games), Deep Q-Networks (DQN) (teaches robots to navigate obstacles, AlphaGo (a model that defeated human champions in the board game Go), autonomous vehicles (autonomous cars driven by artificial intelligence that learn to make driving decisions).

Each type of ML algorithm plays a crucial role in solving different real-world problems, making machine learning a powerful tool in areas such as healthcare, finance, robotics, and more.

4. Machine Learning Solutions to Environmental Challenges in Urban Areas

As urban populations grow, cities face increasingly severe environmental challenges, including air pollution, waste management, water scarcity, and energy inefficiency. Machine learning (ML) can provide innovative and highly effective solutions to these problems by analyzing very large data sets, identifying patterns, and optimizing processes. Below are some of the main applications of ML that can be used to eliminate and/or mitigate environmental problems in urban environments, namely megacities (Bouroche and Dusparic, 2020; Zhang et al., 2024; Sun et al., 2024, Yazdi et al. 2024; Bagheri et al., 2023; Ma et al., 2023).

1. Air quality monitoring and prediction - air pollution, an increasingly prevalent problem in large cities, poses significant health risks. ML models can analyze data from various sensors, weather stations, and traffic patterns to predict air quality levels, allowing authorities to issue timely health advisories and implement mitigation strategies.
2. Smart Traffic Management - Traffic congestion significantly contributes to increased greenhouse gas emissions. ML algorithms can optimize traffic flow by adjusting signal times in real time, reducing idle times and lowering pollution levels to acceptable levels.
3. Smart Waste Collection - Inefficient waste collection leads to environmental degradation, often irreparably. ML-based systems can optimize collection routes based on real-time data from smart bins, reducing fuel consumption and emissions.
4. Automated Recycling Processes - ML-based image recognition can improve recycling efficiency by accurately sorting materials, reducing contamination and improving resource recovery.
5. Water Quality Monitoring - ML algorithms can process sensor data to detect contaminants in water sources, ensuring safe drinking water while enabling real-time and prompt responses to pollution events that occur.
6. Leak Detection in Water Systems - By analyzing pressure and flow data, ML models can identify leaks in water distribution networks, minimizing water losses and conserving resources for more efficient consumption.
7. Energy Optimization - ML can estimate energy demand and optimize consumption in buildings, leading to reduced energy waste and reduced greenhouse gas emissions.
8. Renewable Energy Integration - ML facilitates the integration of renewable energy sources into urban networks by predicting energy production and demand, increasing grid stability.
9. Mitigation of urban heat islands - ML models can identify urban areas that retain heat and suggest interventions such as green roofs or reflective materials to reduce temperatures to desired levels.
10. Flood prediction and management - by analyzing weather patterns and terrain data, ML can predict flood risks, helping with urban planning and prompt and real-time response in case of emergencies.

11. Disaster response optimization - ML improves disaster response by analyzing real-time data to efficiently allocate resources during events such as hurricanes or earthquakes.
12. Sustainable Urban Planning - ML helps design sustainable cities by simulating the environmental impact of different urban planning scenarios, promoting green development.
13. Public transport efficiency - ML can optimize public transport schedules and routes based on passenger data, reducing waiting times and emissions. This can lead to efficient and sustainable public transport.
14. Autonomous vehicle deployment - ML-guided autonomous vehicles can reduce traffic congestion and emissions by optimizing driving patterns and reducing the number of vehicles needed.
15. Noise pollution reduction - ML can analyze urban noise data to identify sources and suggest mitigation strategies, improving urban living conditions.
16. Urban Green Space Management - ML helps monitor and maintain urban green spaces by analyzing satellite imagery and environmental data, thus promoting biodiversity and air quality.
17. Climate Change Modeling - ML improves climate models by processing very large data sets, thus improving the accuracy of predictions and informing decision-makers to adopt appropriate solutions.
18. Carbon Emissions Tracking - ML systems can monitor and analyze carbon emission data, thus helping cities implement effective carbon reduction strategies.
19. Urban Wildlife Conservation - ML can monitor urban wildlife populations and their habitats, aiding conservation efforts and maintaining the ecological balance in many ecosystems.
20. Community Engagement and Education - ML-based platforms can engage citizens by providing personalized information about environmental issues, encouraging community engagement in sustainability initiatives.

Incorporating machine learning into urban environmental strategies offers transformative potential for creating sustainable and resilient cities. By harnessing data-driven insights, urban planners and policymakers can effectively address complex environmental challenges.

In this section it is offered the answer to the second research question, namely "What are the specific aspects of Machine Learning and how can it offer solutions to the challenges specific to large cities. and urban agglomerations?".

5. Methodology and experiment data

As a country, Italy was selected as the country because it had the most complete data regarding waste information at the level of the main cities. The cities that are marked with GC at the end of the name represent the fact that the values taken into account were also those from the suburbs of the city. For this reason the notions of city and greater city are used, the two notions being defined below:

- City: refers to an urban area that has been designated as such by the government, typically based on its population, infrastructure, and administrative functions. It usually includes the central urban core and the surrounding areas that are directly governed by the city council or municipal authorities. A city may be limited to a specific geographic boundary, which can range from a small town to a major metropolitan area.

- Greater City (CG): refers to a larger metropolitan area that includes not only the city proper but also its suburbs, exurbs, and sometimes nearby towns or regions that are economically, socially, or administratively connected to the city. This can encompass multiple smaller municipalities, suburbs, and even rural areas that are part of the city's economic or commuting zone. The term is often used when talking about metropolitan regions, where the city proper might be o nly a small part of the broader urbanized area.

So, it may concluded that a "greater city" encompasses a wider region and often refers to an entire metropolitan area, while a "city" is typically the administrative unit with its defined limits.

The results were obtained using WEKA software, which is open-source software (https://www.cs.waikato.ac.nz/ml/weka/). The methodology employed is a data mining approach known as DM-CRISP-DM (https://www.datascience-pm.com/crisp-dm-2/). This methodology consists of several phases, including requirements gathering, data understanding, data preparation, modeling, evaluation, and deployment.

6. Data analysis experiment and results

The dataset was taken from Eurostat and represents Italy municipal waste generated (domestic and commercial), total - 1000 t for the most important large cities in Italy. The number of instances is 87. Unsupervised learning algorithms were applied in the Machine Learning analysis, namely the EM (Expectation Maximization) and SimpleK-Means algorithms. In order to highlight an evolution of the way in which the cities included in the analysis managed municipal waste generated, two time points were chosen, respectively 2018 (before the COVID-19 pandemic) and 2022 (after the pandemic). Italy was chosen as the country because it had the most complete data for the indicated time points for which the analysis results would be representative. The results of the analysis for the two time points, 2018 and 2022, respectively, are presented below.

Table 1. Italy municipal waste generated (domestic and commercial) for Year 2018

Cluster no.	**Most representative city**	**No. of instances (percent)**	**Median Value of the Cluster** (1000 tone)	**Cities**
Cluster 0	Verona	21 (24%)	102.0552	Verona, Trieste, Perugia, Taranto, **Reggio_Calabria**, **Cagliari_GC**, Padova, Brescia, Modena, Foggia, Piacenza, **Pesaro**,

				Messina, Prato, Parma, Livorno, Reggio_Emilia, Ravenna, Ferrara, Rimini, **Forli**
Cluster 1	Genova	6 (7%)	224.3483	Genova, Firenze, Bari, Bologna, Catania_GC Venezia
Cluster 2	Roma	1 (1%)	1728.43	Roma
Cluster 3	Cremona	55 (63%)	41.3656	Cremona, Trento, Ancona, Pescara_GC, Campobasso, Caserta_GC, Potenza, Catanzaro, Sassari, Salerno, Bolzano, Udine, La_Spezia, Lecce, Barletta, Como, Pisa, Treviso, Varese, Asti, Pavia, Massa, Cosenza_GC, Savona, Matera, Acireale_GC Avellino, Pordenone, Lecco, Altamura, Bitonto, Molfetta, Battipaglia, Bisceglie, Carpi, Cerignola, Gela, Bagheria, Anzio_GC, Sassuolo, Siracusa, Bergamo_GC, Latina, Vicenza, Terni, Novara, Alessandria, Arezzo Grosseto, Brindisi, Trapani, Ragusa, Andria Trani, L_Aquila
Cluster 4	Milano_GC	4 (5%)	487.255	Milano_GC, Napoli_GC, Torino, Palermo

According to Table 1, five main categories have been identified in terms of municipal waste generated. The observations on this table are:
- most cities are located around the value of 41.3656 tons, respectively 55 out of 87, i.e. around 63%. The most representative city is Cremona..

- the city of Rome presents a special situation regarding the management of municipal waste generated, it could constitute a separate cluster due to the value it presents, respectively 1728.43 t.
- at the opposite pole of the city of Rome are the cities in cluster number 3.

Table 2. Italy municipal waste generated (domestic and commercial) for Year 2022

Cluster no.	**Most representative city**	**No. of instances (percent)**	**Median Value of the Cluster** (1000 tone)	**Cities**
Cluster 0	Verona	17 (20%)	102.4182	Verona, Trieste, Perugia, Taranto, Padova, Brescia, Modena, Foggia, Piacenza,

				Messina, Prato, Parma, Livorno, Reggio_Emilia, Ravenna, Ferrara, Rimini,
Cluster 1	Genova	6 (7%)	210.0583	Genova, Firenze, Bari, Bologna, Catania_GC Venezia
Cluster 2	Roma	1 (1%)	1592.31	Roma
Cluster 3	Cremona	59 (68%)	40.8498	Cremona, Trento, Ancona, Pescara_GC, Campobasso, Caserta_GC, Potenza, Catanzaro, Sassari, Salerno, Bolzano, Udine, La_Spezia, Lecce, Barletta, Como, Pisa, Treviso, Varese, Asti, Pavia, Massa, Cosenza_GC, Savona, Matera, Acireale_GC Avellino, Pordenone, Lecco, Altamura, Bitonto, Molfetta, Battipaglia, Bisceglie, Carpi, Cerignola, Gela, Bagheria, Anzio_GC, Sassuolo, Siracusa, Bergamo_GC, Latina, Vicenza, Terni, Novara, Alessandria, Arezzo Grosseto, Brindisi, Trapani, Ragusa, Andria Trani, L_Aquila, **Reggio Calabria, Cagliari_GC, Pesaro, Forli**
Cluster 4	Milano_GC	4 (5%)	478.1825	Milano_GC, Napoli_GC, Torino, Palermo

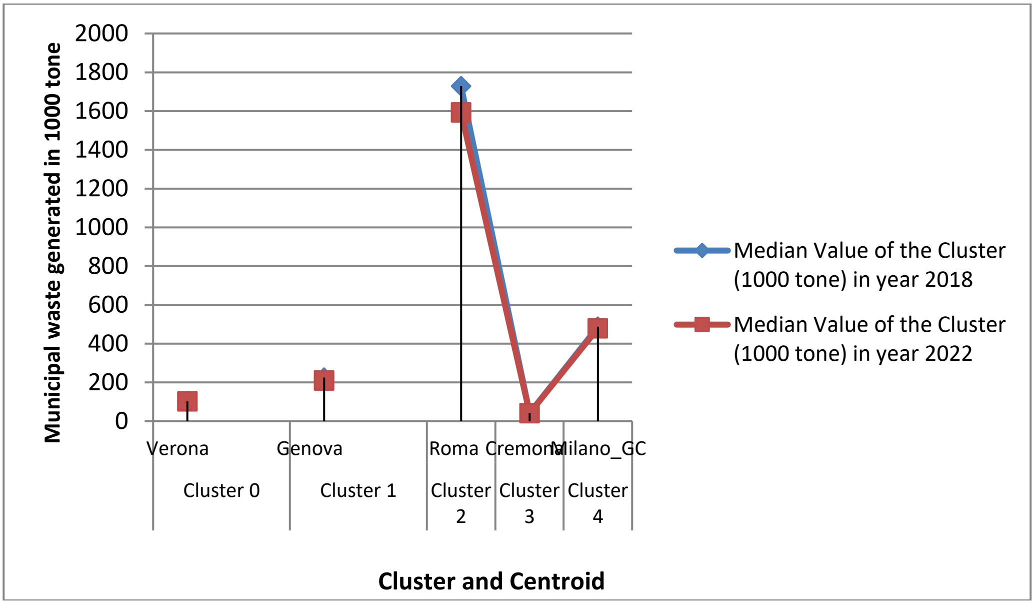

Fig.1 Centroids dynamics of the clusters for years 2018 and 2022(main cities in Italy)

According to Table 2, also five main categories have been identified in terms of municipal waste generated. The observations on this table are:

- most cities are located around the value of 40.8498 tons, respectively 59 out of 87, that is, around 68%. The most representative city is Cremona. A decrease in the average for this cluster can be observed, which is very good from an environmental point of view.
- the city of Rome presents again a special situation in managing municipal waste generated, the related value being 1592.31 t. Here too, an improvement in the situation can be observed although the value remains very high in relation to all the other clusters.
- further at the opposite pole from the city of Rome are the cities in cluster number 3.
- the value for cluster 0 is very similar, this is also around the value of 102 t.
- the most important decrease is for cities in cluster 1, the difference between 2022 and 2018 being approximately 14 t.

Analyzing also from the point of view of the dynamics of the clusters, it can be observed that the cities had a unitary evolution from the point of view of the analyzed aspect, namely municipal waste generated (domestic and commercial). The main differences were for the cities:

- *Reggio_Calabria from cluster 0 in 2018 to cluster 3 in 2022*
- *Cagliari_GC from cluster 0 in 2018 to cluster 3 in 2022*
- *Pesaro from cluster 0 in 2018 to cluster 3 in 2022*
- *Forli from cluster 0 in 2018 to cluster 3 in 2022*

It can be stated that the policies to reduce municipal waste generated (domestic and commercial) had a unitary applicability at the country level, the cities offering a similar response to the need to improve municipal waste generated (domestic and commercial). By applying Machine Learning, it is possible to easily identify the cities that have managed in the present cases to make a very big leap in terms of municipal waste generated. All 4 cities went from an approximate average cluster value of approximately 102 t to 40 t. Such cases and situations should be analyzed and observed what measures were taken to achieve such performances.

In this section, it is offered the answer to the third research question, namely "What is the evolution of the large cities in Italy from an environmental point of view, namely Italy municipal waste generated?"

7. Conclusion

A greener future for big cities can be achieved by integrating advanced technologies, such as Machine Learning, into the management and optimization of urban resources. Intelligent algorithms can analyze massive amounts of data to identify pollution patterns, optimize traffic and improve the energy efficiency of buildings. Thus, local authorities can make data-driven decisions in real time in many respects, such as reducing greenhouse gas emissions and promoting the use of renewable energy sources. Machine

Learning also allows for the monitoring of air and water quality, allowing rapid interventions to prevent deterioration of the urban environment. In addition, the implementation of Machine Learning in big cities that aim to be transformed into smart cities can contribute to the creation of sustainable policies, adapted to the specific needs of each metropolitan area. Thus, the use of Machine Learning can transform big cities into greener, more efficient and more sustainable spaces, providing a balance between economic development and environmental protection.

This paper identifies environmental problems specific to large cities and urban agglomerations, mentions projects and actions taken to combat them at the European Union level, describes specific aspects of Machine Learning, and also describes the correlation and support that Machine Learning can offer to solve the main problems faced by large cities in terms of maintaining a greener and more qualitative environment for its inhabitants. At the end of the paper, a way of using Machine Learning for clustering large cities is presented.

Future research will consist of selecting large data sets on various specific problems and using Machine Learning algorithms to identify possible solutions or data specificity.

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