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ORIGINAL RESEARCH

Unveiling Environmental Crime Trends and Intensity in the EU Countries Through a Sustainability Lens

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Abstract
Environmental crime poses a significant threat to global ecosystems, biodiversity, and human well-being, encompassing activities such as pollution, illegal waste disposal, trade in protected species, and natural resource degradation. Understanding the dynamics of these crimes is essential for devising effective mitigation strategies and promoting sustainability at micro, meso, and macro level. The aim of the study is to examine environmental crimes in the EU, focusing on their current trends, patterns, and Intensity, as well as the impact on sustainability across its three dimensions. Fourteen EU countries environmental crime data from 2016 to 2021were analysed to reveal variations and trends. Geographic information systems (GIS) utilized to identify countries with elevated environmental crime rates, emphasizing the need for interventions in pollution control, waste management, and resource conservation. Results indicate high environmental pollution intensity in Italy, Sweden, and Denmark. Moreover, Italy emerges as the epicentre of illegal waste dumping, with notable cases also present in Belgium and France. Additionally, France, Slovakia, and Italy show alarming levels of illegal wildlife trade. Furthermore, France and Sweden exhibit the highest density of natural resource degradation cases. In addition, the study unveiled a positive correlation ($b > 0$) between environmental pollution, trade in protected species, and natural resource degradation with population growth, while waste disposal exhibited a negative correlation ($b < 0$). Moreover, trade in protected species and resource degradation correlated negatively ($b < 0$) with the poverty ratio. Addressing environmental crimes aligns with the pursuit of green justice, recognizing the interconnectedness of environmental, social, and economic factors. The findings offer valuable insights for policymakers, environmentalists, and communities, guiding interventions towards a sustainable and resilient future.

Keywords Environmental crime · Sustainability challenges · Environmental pollution · Waste dumping · Trade of protected species · Resource degradation

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Introduction

Environmental crime (EVC) is currently ranked as the third-most significant form of criminal activity on a global scale. This illegal practice exhibits a consistent annual growth rate ranging from 5 to 7%. Consequently, the monetary losses of such criminal acts amount to an estimated annual loss of $110 to $281 billion (European Council, 2022). Consequently, EVC is widely recognised as a very lucrative form of organised criminal activity, exerting significant influence on the natural environment, human well-being and establishing green justice. South (2014) is a prominent scholar in the field of green criminology, having made substantial contributions to the advancement of knowledge in this area. Green criminology is the academic discipline that examines the interconnections between environmental degradation, criminal activity and the administration of justice. He advocates a holistic approach that considers social, economic and political contexts in order to effectively address environmental crime. Furthermore, Ruggiero and South (2013) also emphasises the principle of environmental justice, arguing that the negative effects of environmental degradation should not disproportionately affect marginalised communities.

Furthermore, the European Union (EU) is confronting with a multifaceted environmental challenge that demands a comprehensive approach for sustainability. This entails tackling environmental issues at various levels, ranging from individual actions to international cooperation. At the individual or micro level, motivating sustainable practices such as waste reduction, reuse, and recycling is crucial. Besides, raising public awareness through campaigns can significantly curb littering and household waste. These initiatives should aim to unify messaging across the EU's diverse nations, fostering a collective sense of responsibility towards maintaining a clean environment. At the business and organization or meso level, the implementation of stricter waste management legislation will ensure a level playing field across the EU. Investing in environmental technology innovation for sustainable waste management solutions can minimise negative environmental impacts. At the global or macro level, the EU can use its economic and political influence to tackle issues such as wildlife trafficking. Collaborating with international law enforcement agencies helps disrupt trade in protected species and wildlife trafficking networks, which will influence the development of international regulations prioritizing flora and fauna protection (Henle et al., 2013; Vane-Wright et al., 1991).

The EU can establish a synergistic effect by tackling environmental concerns at individual (micro level), organizational (meso level), and international levels (macro level). Increased public awareness strengthens support for strict regulations, which incentivizes individual and businesses to adopt sustainable practices. This holistic approach can solidify the EU's position as a frontrunner in environmental sustainability both at nationally and globally.

Several prior studies have been dedicated to examining the phenomenon of EVC and security. Cheng and Chen (2021) has examined the advancements in comprehending urban crime and formulating security plans, with a particular focus on the adoption of urban security measures and the application of data-driven policing methods. Their study explored that communities affected by crime often experience a range of anxieties and concerns. A study by Barabás and Andrea (2014) identified fear, security, and a general feeling of being unsafe are all major issues, especially for those who have been directly victimized by crime and these concerns require significant attention. However, Kaposzta et al. (2018) studies have

explored the interconnectedness among civil lifestyle, tourism, and security, which focusing on the challenges stemming from economic downturns, cybercrime, and terrorism activities.

Furthermore, Onyeneke and Karam (2022) uncovered a link between socioeconomic inequality, poverty, and the prevalence of crime in urban areas. However, the study by De Nadai et al. (2020) finds a correlation between violent and property crime, socio-economic indicators (GDP, unemployment rate, poverty ratio, crime rate) and the mobility features of the regions. Ergun et al. (2003) found an association between educational success, age groups, and criminal activity. They also discovered a link between substantial rise in crime incidence in communities with a diverse population growth. Ince and Yavuz (2013) have utilized spatial analysis techniques to investigate the factors influencing crime rates in EU countries. Their result revealed a significant interconnection between crime rates and several economic and social indicators, such as the unemployment rate, poverty ratio, education level, and GDP. Previous research has collectively confirmed the correlation between economic and social conditions and the incidence of criminal activity in EU urban areas.

However, there's a critical gap in our understanding of four types of environmental crimes such as environmental pollution, dumping of waste, trade in protected species, and degradation of natural resources in the selected 14 European countries including Austria, Belgium, Croatia, Denmark, France, Hungary, Italy, Latvia, Netherlands, Norway, Poland, Slovakia, Slovenia, and Sweden. While there is research on EVC, it hasn't delved deeply at the influence of overarching environmental factors (such as the overall economy), social factors (such as the population growth rate), and individual economic factors (such as multidimensional poverty ratio) influence crime rates at different levels, from entire countries (macro) down to neighbourhoods (micro).

The primary objective of this article is to investigate the current trend, pattern, and Intensity of environmental crimes affecting the three dimensions of sustainability in the selected 14 EU countries. Additionally, this study seeks to mitigate the adverse effects of EVC on sustainability by examining its impacts and proposing strategies for intervention and prevention. The researcher aims to shed light on the changing dynamics of environmental crimes, which is significant for governments, policymakers, and environmental agencies to address environmental challenges.

Literature Review

Conceptualization of Environmental Crime

EVC incorporates various illegal activities that degrade and damage the environment and over exploitation of natural resources. These offenses may include but are not limited to illegal logging, deforestation, wildlife smuggling, illegal fishing, air, and water pollution etc. These harmful activities cause serious damage to our planet, degrade ecosystems, biodiversity, and hinder our efforts to create a sustainable future (Lirëza & Koçi, 2023).

Furthermore, Mohamed Adnan et al. (2023) acknowledged that various multinational corporations engage in EVC being pinpointed as significant contributors to environmental damage. In the realm of agribusiness, Schilling-Vacaflor and Gustafsson (2023) found that adopting inappropriate agricultural practices could lead to breaches of environmental regulations. In addition, Hall (2018) highlights the serious consequences of forest-related

crimes, such as illegal logging and deforestation, which endanger ecosystems, human health, and economic stability. Additionally, sustainability and EVC intersect when human actions negatively impact the environment, which jeopardizing its ability to support life in the long term.

Furthermore, environmental pollution continues to pose significant challenges to sustainability in the EU. The air pollution remains the single largest environmental health risk in Europe, causing premature deaths and disease. The study by Jiřík et al. (2024) shows that air pollution in the EU is still a major health risk, causing premature deaths and illnesses. Their study emphasizes the need for more stringent regulations and enforcement to reduce air pollution and promote sustainability. Nevertheless, further action is required to achieve sustainability, including the advancement of clean energy and the reduction of greenhouse gas emissions.

However, environmental crimes are a significant threat to both the environment and communities, increasing susceptibility to disease, environmental disasters, pollution, and species loss (Lirëza & Koçi, 2023). These lead to reduced life expectancy, increased disease rates and contamination of the food chain (Fegadel, 2021). Criminal activity exacerbates social, cultural, and economic inequality, particularly affecting marginalized populations (Bruinsma & Johnson, 2018). In addition, environmental crimes are often associated with inadequate governance, corruption, and limited financial resources for law enforcement (Naghavi, 2019). The research conducted by Kerezsi and Lévay (2008) provides significant insights into the complexities of environmental crime and governance. In her case studies, she examines the prevalence of corruption in environmental enforcement and the challenges associated with implementing effective environmental regulations. Based on her findings, Kerezsi proposes a series of policy reforms aimed at enhancing environmental governance. These reforms encompass measures to enhance transparency, accountability, and public participation in environmental decision-making.

Illegal waste dumping is a growing concern for sustainability in the EU. Such practices have the potential to result in a variety of negative consequences, including soil and water pollution, adverse impacts on wildlife, and potential risks to human health. Patil et al. (2024) have identified illegal waste dumping as a primary source of soil and water pollution, wildlife endangerment, and threatening human health. The authors mentioned that the EU has implemented regulations to prevent waste and promote recycling, such as the Waste Framework Directive (EC Directive, 2008). However, they argue that enforcement of these regulations remains a challenge, and more research is needed on waste management practice to understand the extent and impacts of illegal waste dumping in the EU. Moreover, the illegal disposal of hazardous waste and water pollution, both distinct environmental crimes committed at the corporate level, pose a significant threat to water resources. It is evident that improvements are required in the systems deployed for the prevention detection, administration and control of criminal activities (Segato et al., 2020).

The connection between sustainability and EVC lies in the fact that environmental crimes directly undermine efforts toward achieving sustainable development, resulting in resource depletion, ecosystem degradation, contributions to climate change, and exacerbation of social inequalities (Seiyefa & Oyosoro, 2024). Additionally, environmental crimes often disproportionately impact marginalized communities reliant on natural resources for their sustenance. Consequently, resource degradation poses significant challenges to sustainability in the EU. Ruiz Serrano et al. (2024) found that overexploitation of resources,

such as fisheries and forests, can lead to resource depletion and ecosystem. The authors observe that the European Union has enacted policies to encourage the sustainable use of resources, including the Common Fisheries Policy (European Commission, 2023a) and the Forest Strategy (European Commission, 2023b). However, they argue for the promotion of circular economy principles as a key step to ensuring the long-term sustainability of these resources.

Furthermore, Savona (2000) emphasises the transnational nature of the intersection between organized crime and environmental crime. His research shows that criminal organizations exploit environmental regulations to their advantage. In general, they are involved in illegal activities such as waste disposal and wildlife trafficking. However, wildlife trafficking is a significant threat to sustainability, undermining biodiversity and ecosystem health. Such activities not only violate legal and regulatory obligations, but also inflict substantial damage on the environment. In addition, E. Savona and Williams (2012) emphasizes the necessity for a transnational approach to these crimes, underscoring the importance of international cooperation to effectively address such issues on a global scale. As evidenced by a study conducted by Mozer and Prost (2023), the European Union functions as both a destination and a transit point for illicit wildlife products. The authors note that the EU has adopted an Action Plan against wildlife trafficking (Yildirim & Lohan, 2022). However, they argue that more substantial action is needed to tackle the root causes of wildlife trafficking, including poverty and lack of alternative livelihoods.

Tackling EVC is essential to achieving sustainability goals (Islam & Wang, 2023). Effective enforcement of environmental laws and regulations is crucial, alongside the promotion of transparency, accountability, and good governance. Furthermore, addressing the root causes of EVC, such as poverty, lack of alternative livelihoods, and weak regulatory frameworks are essential for achieving sustainable development (Kaiser, 2023).

However, the main challenges to reaching our goals for sustainable development is environmental crimes, which include good governance, gaps in our systems for conserving and protecting the environment, not having enough resources to enforce the rules, dealing with the complexities of illegal activities that cross borders, and facing issues like money laundering, fraud, and corruption (Elliott, 2022). Understanding the historical and social context of environmental justice is important if we want to make progress towards sustainable development (Collin, 2019). So, it's important to identify environmental crime at the micro, meso, and macro levels, because that's the only way we can deal with the problem effectively.

The Sustainability-Environmental Crime Nexus: Exploring the Interconnections

The negative impact on a region's sustainability is arguably the most important way of expressing and quantifying the damaged inflicted by environmental aggression. The concept of sustainability pertains to the objective of attaining a continuous state of environmental balance, wherein resources are utilised in a manner that prevents their depletion or irreversible loss.

According to der Ryn (1986), the fundamental principle of sustainability is to ensure that present decisions do not hinder the ability to maintain or enhance future living standards. This perception also repeated by Visser and Brundtland (1987), encompasses meeting the current needs of society without endangering the ability of future generations to fulfil their

own needs. This sustainability concept considers the economic, social, and environmental aspects, acknowledging their interconnectedness and mutual reliance. In addition, the principles of sustainability encompass the objective of mitigating the depletion of environmental resources, alongside the promotion of economic and social integrity, as well as the equitable distribution of benefits (Rogers et al., 2012; UN, 2014). Consequently, sustainability and environmental crimes are connected in the same nexus.

Furthermore, conventional criminological study primarily focuses on understanding criminal behaviour through the lens of offenders' characteristics and life experiences. However, the environmental perspective in criminology presents a distinctive viewpoint. It views crime as a complex phenomenon influenced by various factors beyond individual behaviour rather than solely attributing crime to the deviant behaviour of offenders. This intricate perspective examines broader dynamics such as crime patterns over time and place, victim profiles, and types of crimes (Poppi, 2023). However, location plays a significant role in environmental criminology as evidenced by the enduring interest in understanding crime within different spatial contexts. Crime theories offer explanations at various spatial scales, ranging from national and regional levels to the micro-level of neighbourhoods and street segments (Theron et al., 2023). However, environmental criminology shift from micro-level to macro-level studies, reflects a growing recognition of the importance of environmental factors in shaping crime patterns (Friendly, 2007). A study byEman & Bulovec (2021) on environmental crime in Europe highlights the urgent need for a unified approach across EU countries in order to effectively address this issue. She underscores the significance of an interdisciplinary approach that integrates criminological, legal, and environmental perspectives. She emphasises the importance of an interdisciplinary approach, combining criminological, legal and environmental perspectives. Her work contributes to a deeper understanding of the challenges and potential solutions to environmental crime within the European context.

Furthermore, EVC poses threats to three main aspects of sustainability such as environmental, social, and economic. Addressing these crimes requires robust prosecution and prevention mechanisms aimed at safeguarding ecosystems, wildlife populations, and biodiversity. Through examining the concepts of sustainability and EVC, researchers have identified the connections between them. This assessment has shed light on how the different aspects of sustainability (economic, social, and environmental) are linked to various types of environmental crimes (Table 1).

Environmental crimes manifest at diverse levels, each necessitating distinct approaches for deterrence and prosecution. At the individual (Micro) level, offenses like littering, illicit disposal of household waste, and unauthorized exploitation of local resources contribute significantly to environmental deterioration. Addressing these micro-level crimes raises community accountability and fosters the adoption of sustainable behaviours at grassroots levels.

Transitioning to the organizational sphere, focus shifts to enterprises and institutions (meso-level) whose operations may pose environmental threats. For examples, unlawful deforestation by local corporations, improper industrial waste handling, and disregard for environmental statutes by agricultural ventures are meso-level crime. These types of business entity legally responsible for non-sustainable practices and accountable for mitigating the ecological impacts for their actions.

Table 1 Interconnection between sustainability and environmental crimes

Sl.	Sustainability Dimensions	Impact of Environmental Crime	Interconnection
1.	Environmental	The adverse effects of environmental crimes on ecosystems	The environmental pillar of sustainability affects due to activities like poaching and forest destruction. These activities have detrimental effects on natural habitats, wildlife populations, and overall biodiversity in the EU.
2.	Social	The impacts of environmental crimes on human well-being	Communities encounter a substantial social impact on their sustainability due to the correlation between environmental pollution and adverse health impacts, such as respiratory illnesses and contaminated local water supplies.
3.	Economical	The economic consequences of environmental offences	Sustainability is negatively impacted by criminal activities associated economic costs for repairing the damage and restoration of ecosystems.

At the macro-level, environmental crimes escalate in scope, encompassing activities like international wildlife trafficking, cross-border dumping of hazardous substances, and the enactment of policies with comprehensive environmental ramifications. Identifying and combating these large-scale offenses is critical for dismantling criminal syndicates, nurturing global collaboration on environmental fronts, and enacting robust legislation to safeguard the planet on a global scale. Through collective efforts targeting environmental crimes across all tiers, from individual behaviours to global policies, progresses should be made towards a sustainable and environmentally conscious future.

The Scales of Environmental Crime: From Individual to International

Micro Level

Micro-level crimes are generally committed by individuals or small groups, whose activities may include dumping waste illegally, unauthorised waste disposal, illegal fishing, and so on. Consequently, many studies have been conducted to observe EVC at the micro level within diverse contexts. Cinar and Cubukcu (2018) examined the correlation between crime, fear, and micro-level physical EVC. These physical environmental crimes include physical assault, places for concealment opportunities, reduced visibility of potential dangers, and restricted escape. Also, Barclay and Bartel (2015) specifically investigated cases of environmental damage that take place in agricultural settings. The principal objective of their research was to analyse the perceptions of farmers about these detrimental activities to categorise them as EVC (Cinar & Cubukcu, 2012). Dugato (2022) initiated the concept

of spatial crime risk assessment and explored environmental variables that may influence criminal activities. In addition, Bernasco (2010); and Poppi (2023) analyzed the spatial preferences of criminals, engaging discrete choice models to get insights into the decision-making process behind illegal place selection, time and space, victim profiles. These studies highlight the significance of micro-level (Individual) elements EVC.

Meso Level

Environmental crimes at the meso level typically occur within businesses and organizations (Vaughan, 2007). On a meso-level, larger entities such as corporations or organized groups might partake in crimes like trading protected species. Besides, these offenses are often driven by financial motives and involve activities like illegal trading of protected wildlife, unauthorized logging, improper waste disposal, and violations of environmental laws and regulations. Environmental crimes from this economic perspective involves an analysis of monetary systems, the significance of environmental performance for businesses, the money laundering practice, the conduct of financial investigations, and the accomplishment of regulatory measures and sanctions (Carpenter & Nevin, 2010). van Uhm and Moreto (2017) examine the global scale of illegal wildlife trafficking and its impact on biodiversity, conservation efforts and economic stability. It highlights organized criminal networks' involvement and emphasizes a need for comprehensive policies that address both demand and supply aspects of wildlife trade.

However, the nature of this meso-level crimes extends globally and have significant impacts on various aspects such as economic stability, livelihoods, the advancement of effective governance, and the enforcement of legal frameworks (Seiyefa & Oyosoro, 2024). A study by Kolawole and Iyiola (2023) identified the key environmental concerns contributing to these illegal activities include air, water, and land pollution, and waste management challenges. However, reducing and proving environmental crimes may have greater challenges. The inconsistency in addressing these crimes, difficulties in ascertaining liability, establishing causality, and estimating the boundary of damage (Naghavi, 2019). Preventive measures for meso-level environmental crimes involve various techniques, such as enacting legislative modifications, delivering training programs, offering alternative penalty options, promoting public engagement, and applying criminal responsibility frameworks for corporate organizations (Golubev et al., 2020). Advance technologies and tools like satellite imagery, blockchain technology, big data analytics can be utilized as critical weapon to reduce environmental crimes at corporate level.

Macro Level

Larger scale environmental crimes occur on national, government, and multinational corporation levels. These macro-level crimes contain the degradation of natural resources like large-scale deforestation, industrial pollution, illegal fishing in international waters, and the violation of international environmental treaties and agreements.

Furthermore, macro-level crimes studies utilize sociological and psychological perspectives to investigate how environmental factors affect criminal behaviour (Herold & Bürger, 2023). Additionally, Sahramäki and Kankaanranta (2023) highlight the importance of enforcement mechanisms, governance structures and awareness campaigns in preventing

EVC. However, an effective approach needs for addressing the concern at multiple levels. It entails immediate action to mitigate the problem, disrupting the underlying systems contributing to it, and implementing measures to prevent its recurrence in the future.

The EU needs a versatile strategy to achieve sustainability by reducing environmental crimes. Consequently, the researcher emphasizes the necessity of a comprehensive strategy to combat environmental crimes by targeting individual's improper waste dumping behavior (micro), enforcing stricter regulations on waste management for businesses and dismantle wildlife trafficking networks (meso), and collaborating globally to reduce environmental pollution and degradation of natural resources (macro). In addition, the researcher developed a model to classify environmental crimes based on different levels such as individual actions, organizational practices, and international policies. This model aims to identifying the different scales of environmental crime and unravel intricate issues such as pollution, waste management, illegal wildlife trade, and resource depletion, facilitating targeted interventions. Also, this model will identify what types of crime affecting the three dimensions of sustainability.

Figure 1 illustrates the correlation between the intensity of environmental crime and sustainability pillars such as environmental, social, and economic. Through the analysis of environmental crime, the researcher has categorized it into three distinct levels such as micro, meso, and macro. These levels have been identified as having significant impacts on the environmental, social, and economic components. Based on these three crime levels, various global initiatives and frameworks strive to address EVC and advance sustainability by assessing the severity of criminal activity.

Tackling the EVC effectively at micro, meso, and macro level is a game changer for protecting our planet and to get significant advantages for sustainability. Firstly, it directly reduces environmental harm caused by illegal activities. Secondly, this will prevent EVC by showcasing a firm stance against environmental offenses across all levels. Lastly, understanding these three levels of crimes will assist to create better policies and regulations.

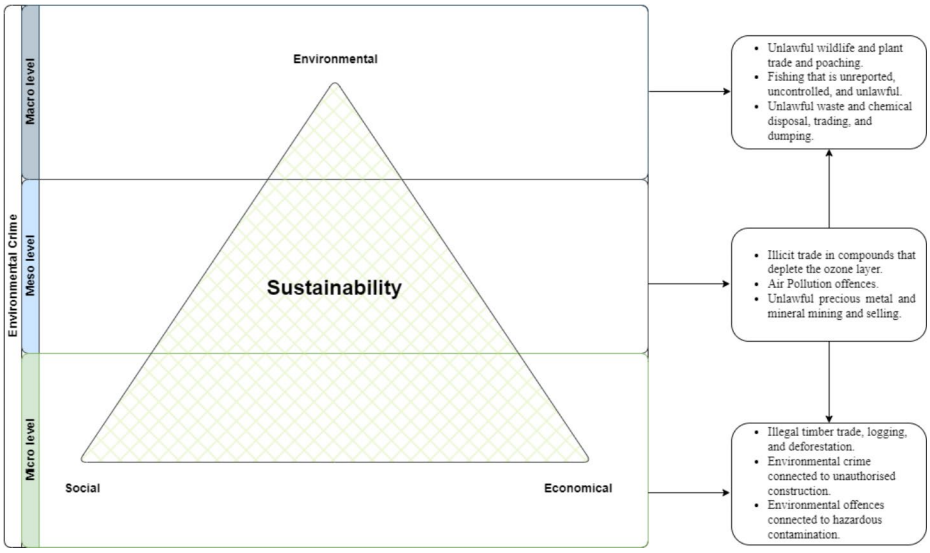

Fig. 1 Environmental crime intensity and sustainability indicators model

By using this model and taking a multi-layered approach, researchers and policymakers can gain a much deeper understanding of EVC. This integrated strategy sets the stage for a more sustainable future. However, effective solutions for sustainability and combating environmental threats worldwide depend on collaboration between governments, civil society, environmental agencies, and international organizations.

Materials and Methods

The researcher applied a combination of statistical analysis, data visualisation, and sustainability principles to deliver a nuanced understanding of EVC pattern, trends, and countries with significant environmental crime issues. The environmental crime data was collected from the United Nations Office on Drugs and Crime (UNODC) database (United Nations, 2023). Additionally, population growth and multidimensional poverty ration data obtained from Our World in Data (2023b, 2023a). The dataset contains 6-year (from 2016 to 2021) information on environmental pollution, dumping of waste, trade in protected species, and degradation of natural resources of 14 EU countries. Data preprocessing involves cleaning and organizing the dataset. Steps include removing missing or inconsistent entries, ensuring data integrity, and extracting relevant information such as countries, years, and crime variables. All analysis conducted by Matlab version R2024a and Python V3.12.4.

Temporal trends are examined for each EVC variable over the specified years. Line plots are generated using Matlab to visualize changes in pollution, waste dumping, trade in protected species, and resource degradation. Researchers use linear regression as a typical method to establish a mathematical model that describes the connection between a dependent variable Y, such as pollution levels, and X is the independent variable representing the years. The equation for this linear regression model is represented below:

$$Y = \beta_0 + \beta_1 \cdot X + \epsilon \tag{1}$$

Here β_0 is the intercept term and β_1 is the slope coefficient rate changes over time. However, ϵ representing the error term. Here the main objective is to determine the values of β_0 and β_1 that result in a model that accurately represents the observed data.

Spatial analysis was performed using Python and geographic information systems (GIS) techniques used to investigate patterns and crime intensity of EVC across countries. The EVC data were aggregated by country, summing up the total number of incidents for each type of crime. This aggregation was achieved by using the following formula:

$$\text{Total Crime}_{country} = \sum_{i=1}^{n} \text{Crime}_i \tag{2}$$

here $\text{Total Crime}_{country}$ represents the total number of crimes in a specific country and Crime_i denotes individual crime counts.

The shapefile of the EU obtained from the Natural Earth database. In python $GeoPandas$ was used to acquire spatial data. This shapefile contains geometrical representations of 14 EU countries, including their boundaries and shapes. The aggregated EVC data were merged with the EU shapefile based on the country names. This integration allowed for the spatial

representation of EVC data on the EU map. Among selected four variables, each variable was plotted separately on a map by using the $Folium$ library. The $StamenTerrain$ tile layer was added to enhance visualization. the intensity of each EVC type across 14 countries. This step facilitated the identification of countries and improved the interpretability of the maps. The maps were analysed to identify spatial patterns and high EVC prevalence country. Patterns of concentration or dispersion of different types of crimes were examined to gain insights into the geographical distribution of environmental risks.

However, the means calculation is necessary to understand the central tendency of the dataset. The mean is calculated in MATLAB by using the $accumarray$ function with the $@mean$ function handle. The $accumarray$ function groups the EVC data by EU countries, and for each group, it calculates the mean of the 4 variables including, Environmental pollution, Dumping of waste, Trade of protected species of faune and flora, and the depletion of degradation of natural resources. The mean value is calculated using the sum of all values and divided by the total number of values. Which can be defined as:

$$Mean\,(\overline{x}) = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3}$$

Here $\overline{x}$ is the mean, n is the total number of data points (years) for that country. x_i represent the variable and individual value for each year. For example, pollution value for each year means x = Environmental pollution and i = year.

The pie chart illustrates the distribution of EVC across various countries and categories. Each slice of the pie represents a country's contribution to the total EVC within a specific category, expressed as a percentage of the total. The percentage value for each slice is calculated by dividing the mean value of EVC for that country within the category by the total mean value of EVC for all countries in the same category, and then multiplying by 100 to express it as a percentage. The equation used to calculate the percentage is:

$$Percentage = \left(\frac{MeanValueofCountry}{TotalMeanValueofallCountries}\right) \times\ 100 \tag{4}$$

The legend beside the pie chart includes the country names along with their respective percentages, providing a clear visual representation of each country's contribution to EVC within each category. This allows for easy comparison and interpretation of the data, enabling insights into the distribution and patterns of environmental offenses across different countries.

The researcher utilizes linear regression analysis in Python to investigate the association between various environmental factors (X) (such as pollution, waste dumping, trade of protected species, and natural resource degradation) and population growth (Y). Each environmental factor serves as an independent variable, while population growth is the dependent variable. The linear regression model used here is of the form:

$$Y\ =\ \beta_0 + \beta_1 X + \in \tag{5}$$

The regression model aims to discern whether there exists a linear relationship between these factors, characterized by a slope (β_1) (representing the change in population growth

per unit change in the environmental factor) and an intercept (β_0) (indicating the expected population growth when the environmental factor is zero). The $stats.linregress$ function from the $scipy.stats$ module computes the regression coefficients, including the slope, intercept, correlation coefficient (r), p-value, and standard error $(?)$, providing insights into the strength and significance of the relationships.

Subsequently, the code plots scatter plots for each environmental crimes against population growth, accompanied by the corresponding regression line. The regression line equation is of the form:

$$PopulationGrowth\,(Y) = Intercept\,(a) + Slope\,(b) \times\ EnvironmentalCrimes\,(X) \quad (6)$$

In this model, population growth is represented by the variable Y, the intercept a, and the slope b. Environmental crimes are represented by the variable X, which helps in intuitively understanding the observed relationships. Each regression line represents the estimated linear association between an environmental factor and population growth, providing a clear indication of the direction and magnitude of the impact.

Also, linear regression applied for investigating the multidimensional poverty ratio on environmental factors. each environmental factor (X) serves as an independent variable, while the poverty ratio (Y) is the dependent variable. The $stats.linregress$ function from the $scipy.stats$ module calculates the regression coefficients (slope, intercept, correlation coefficient, p-value, and standard error) for each environmental factor and the poverty ratio.

Subsequently, the scatter plots for each environmental factor against the poverty ratio, accompanied by the corresponding regression line.

$$PovertyRatio\,(Y) = Intercept\,(a) + Slope\,(b) \times\ EnvironmentalCrimes\,(X) \quad (7)$$

This analysis helps to understand the relationship between environmental crimes and multidimensional poverty ratio. The regression line represents the estimated linear association between an EVC and the poverty ratio, providing insights into how environmental factors may affect poverty levels.

Analysis and Results

The European Union (EU) has implemented measures to address criminal networks engaged in many types of EVC, such as waste management regulations and regulations governing the trafficking of wildlife and flora. The European Union is currently engaged in efforts to enhance the efficacy of existing environmental protection regulations through criminal law. However, prior to implementing measures against EVC, it is imperative to conduct a detailed analysis of the crime and safety index of European Union countries.

The Fig. 2 depicts EVC trends in 14 European countries from 2016 to 2021 (calculated by using Eq. 1). Each country's data is represented by a line on the graph, with the y-axis indicating the number of reported incidents and the x-axis representing time. The first variable environmental pollution shows diverse patterns over the years. The trend depicts the number of pollution incidents identified during this period, revealing a concerning trend. Pollution levels are continue rising beyond 2020, with detrimental effects on both the envi-

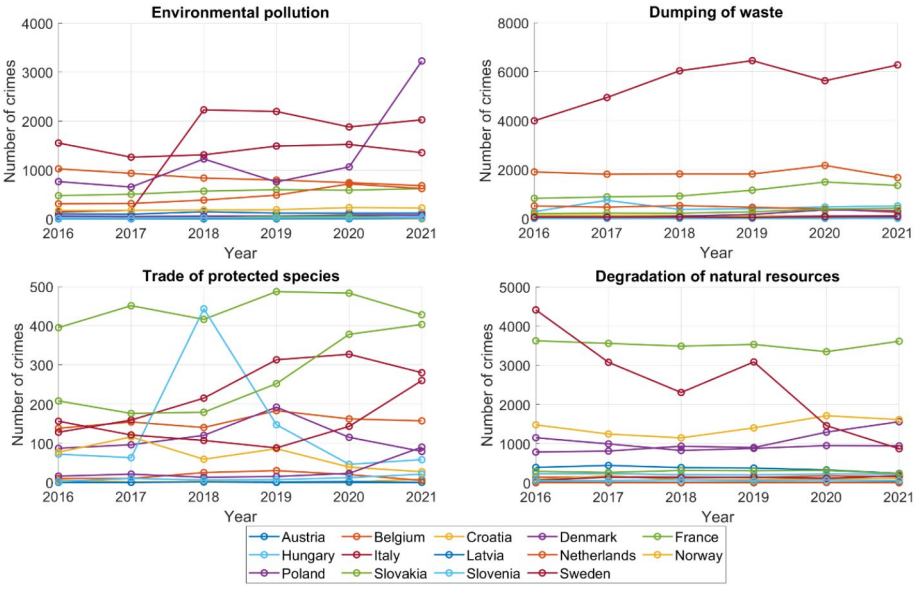

Fig. 2 Environmental crime trends across fourteen European countries

ronment and human health. There is a fluctuating trend in environmental pollution with peaks and dips observed over the years. For example, Austria experienced a slight rise of pollutions in 2018, while Belgium and the Netherlands shown a general decrease. However, Denmark and Italy showed significant increases after 2020. This escalation can be attributed to inadequate regulation and the expansion of industrial activities. France demonstrated relatively stable pollution rates throughout the years, while Latvia consistently reported low counts. These variations highlight the nuanced tactics to pollution management, which influenced by different factors such as regulatory frameworks and industrial activities.

The second variable is waste dumping exhibited fluctuating trends across different EU countries. Austria has shown a rising trend in waste dumping since 2016. After 2018 this trend dramatically decreased and become stable till 2021. Belgium experienced slight fluctuations, but there was fairly increase from 2019 to 2020, followed by a decline in 2021. France has consistently shown an increasing trend in waste dumping throughout the period analysed. Italy exhibited an upward trend in waste dumping from 2016 to 2021. The Netherlands showed fluctuations with a potential rise between 2016 and 2020, followed by a decrease in 2021. Poland saw a significant increase in waste dumping between 2018 and 2020, followed by a decrease in 2021. Denmark displayed fluctuations but hinted at an overall decrease in waste dumping. Latvia showed waste dumping seeming stable or slightly increasing. Norway showed a potential decreasing trend in waste dumping. Sweden showed fluctuations with a possible slight increase.

Various factors could influence these trends, including economic factors, and waste management policies. Economic growth typically correlates with increased consumption and waste generation, while economic downturns may lead to reduced waste production. Additionally, the implementation of stricter regulations or investments in improved waste management infrastructure could contribute to a decrease in waste dumping.

The third variable is trade of protected species generally showed fluctuations among most of the countries. The EVC has been observed in Hungary (2018) and Poland (2021) in a seemingly random manner. Trade in protected species appeared minimal for Austria. In contrast, France showed an overall increase since 2016 and spiked more in 2019. Similarly, Italy's trends suggest a potential increase in trade of protected species from 2016 to 2021.

The fourth variable degradation of natural resources also showed fluctuations across the selected EU countries. Austria exhibited a slight increase. However, France is mostly responsible for depletion of resource displayed a slight decrease in 2020 followed by an increase in 2021. There was a steady increase EVC trend in Croatia and Denmark. Norway showing fluctuation trend. Poland and Sweden showing consistently decreasing trend from 2016 to 2021.

Furthermore, all 14 EU countries reveal various trends in EVC. Austria saw a slight increase in environmental pollution over time, with waste dumping fluctuating but generally rising from 2020 to 2021. While Denmark and Sweden witnessed fluctuations in natural resource degradation. In contract, Norway maintained relatively stable counts over time. Poland experienced a slight increase in natural resource degradation, while France reported a significant uptick in 2021. These EVC trends reveal a complex interplay between human activities and conservation efforts, socioeconomic factors, and environmental policies.

Figure 3 provides a comprehensive overview of EVC intensity across 14 EU countries from 2016 to 2021 (calculated by using Eq. 2). Four maps visually depict the distribution and severity of various environmental crimes throughout this region. Each EU nation is represented by circles proportional to the intensity of these environmental offenses, with colour variations indicating the specific crime types. In fostering environmental protection efforts, this in-depth analysis facilitates a side-by-side comparison of EVC intensity across various countries. This also reveal the EVC areas that necessitate prioritized environmental interventions.

The first map illustrates the distribution and intensity of environmental pollution across 14 EU countries, with larger blue circles indicating higher pollution levels. Italy stands out with a highest pollution level, registering an index of 8644. This raises serious environmental concerns. Denmark also reveals a critical concentration of incidents at 7679, highlighting significant environmental issues. Notably, Sweden shows the significant level of pollution on the map, reaching an intensity of 8482, signalling severe environmental challenges.

France exhibits moderate pollution levels with an intensity of 3349. Belgium shows a noticeable pollution concentration with 5003 incidents, while the Netherlands presents moderate pollution intensity at 2830, primarily located in its central area. In a striking comparison, Latvia presents a minimal pollution profile, boasting an intensity score of merely 27. This suggests that the country grapples with relatively few environmental issues, offering a fresher and cleaner atmosphere. Both Slovakia and Slovenia have very low pollution levels, with intensities of 169 and 115 respectively, suggesting minor environmental issues. Poland's pollution intensity is also low at 380.

Overall, the countries with the highest pollution levels are Italy, Sweden, and Denmark, while moderate levels are observed in Belgium, France, and the Netherlands. Latvia, Slovakia, Slovenia, and Poland exhibit minimal pollution levels. In contrast, Austria, Hungary, and Croatia show negligible pollution, indicating low environmental impact. This positive trend can be attributed to one of two possibilities. Either these regions benefit from inher-

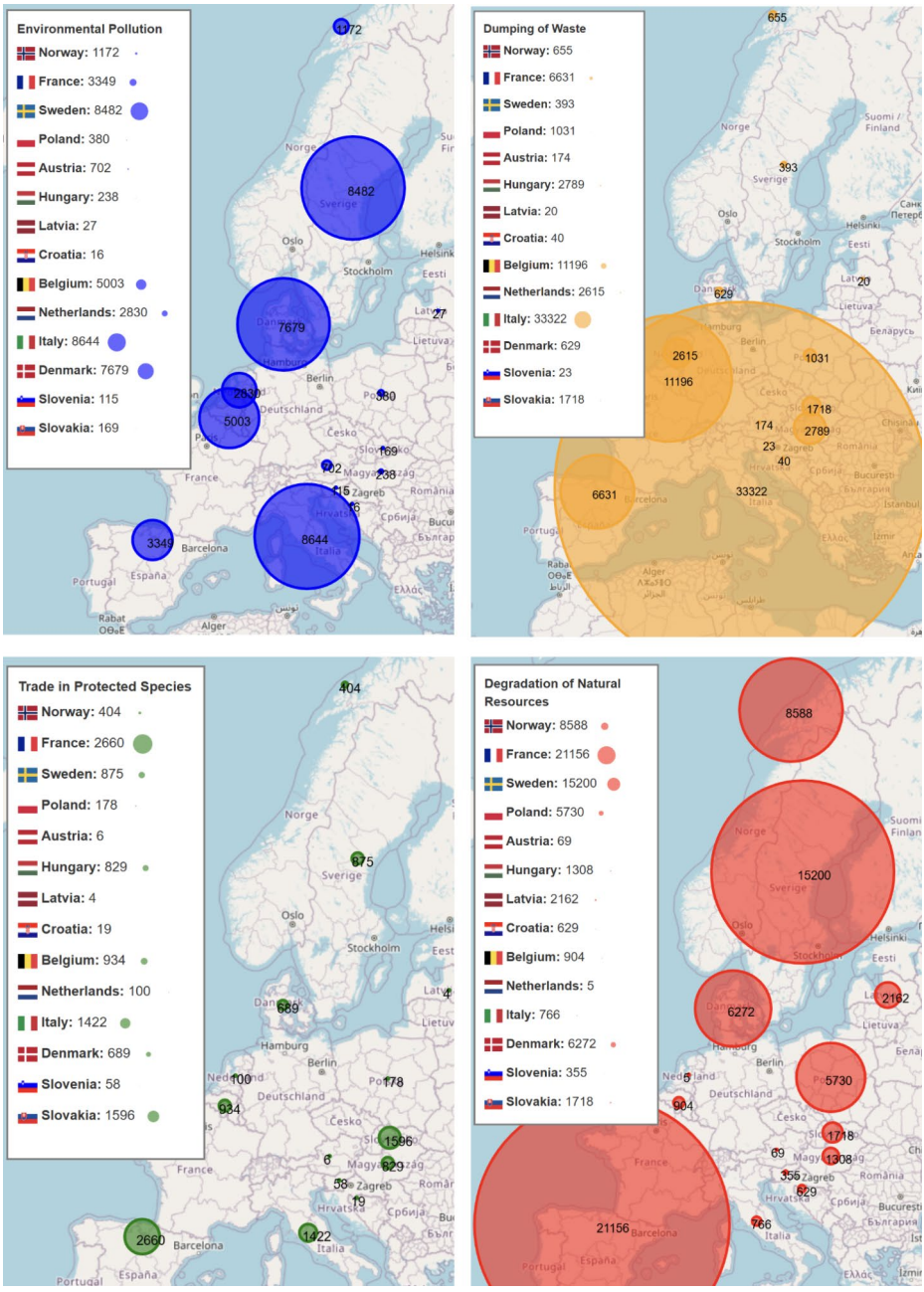

Fig. 3 Geospatial distribution and intensity of environmental crimes across 14 EU countries

ently clean environments, or their environmental management practices are demonstrably successful.

The second map focuses on illegal waste dumping, represented by the size of orange circles. Italy emerges as the country with the most significant issue, showing a concentration of 33,322 incidents. Belgium faces substantial challenges as well, with 11,196 incidents, and France exhibits a high intensity with 6631 incidents. In Denmark, illegal waste dumping is less pronounced, with 629 incidents, while Sweden reports a moderate intensity of 393 incidents. Slovakia and Poland also demonstrate significant concerns, with 1718 and 1031 incidents, respectively. Hungary and the Netherlands experience similar issues, albeit with fewer incidents, totalling 2789 and 2615. Croatia, Austria, and Latvia show minimal illegal waste dumping, indicating relatively minor.

Italy emerged as the epicentre of the illegal waste dumping crime, followed by significant cases in Belgium and France. However, France and the Netherlands exhibit moderate levels. This visual representation serves as a critical tool for identifying areas that require targeted policy and remediation efforts to tackle illegal waste dumping across these EU countries.

The third map takes a different approach, using green circles to paint a picture of illegal wildlife trade. Unlike the previous maps, this one reveals a more dispersed pattern, with numerous smaller-scale incidents scattered across the map. This scattered distribution highlights activity in France, the Netherlands, Italy, and even Scandinavia, indicating a broader issue beyond previously identified crime intensive areas. France exhibits a concerningly high level of illegal wildlife trade, with reported incidents reaching 2660. Slovakia and Italy show substantial EVC activity with 1596 and 1422 incidents, indicating another critical region. Belgium and Hungary also stand out with 934 and 829 incidents, respectively. In Northern Europe, Sweden records a relatively lower yet significant number of EVC incidents at 875. However, Denmark shows a smaller cluster of 689 incidents, indicating less crime activity compared to its neighbours.

The final map depicts natural resource degradation, with crime intensity represented by red circles. France exhibits the highest density, with a significant circle representing 21,156 reported environmental crime cases. This highlights substantial difficulties in managing natural resources and emphasizes the urgent need for improved conservation efforts. Sweden follows with 15,200 cases, highlighting significant issues despite its reputation for environmental stewardship. Norway and Denmark have emerged as countries with new prevalence of environmental crimes. This is concerning due to the high number of reported incidents relative to their population size. Consequently, 8588 incidents in Norway and 6272 in Denmark raise concerns about resource management. Poland also faces challenges, with 5730 reported incidents concentrated in its central region. Other countries report fewer incidents, with Latvia showing 2162 cases, while Austria, Croatia, Hungary, and Slovenia exhibit lower numbers ranging from 69 to 1718 incidents.

Together, these maps provide a nuanced view of environmental crimes across Europe, illustrating that while some issues like pollution and waste dumping are widespread and severe, others, such as the trade in protected species, occur on a smaller scale but are geographically dispersed. The analytical result suggests that central Europe and Italy face complex environmental challenges that may necessitate coordinated, cross-border strategies for effective resolution.

The EVC trends of each country contains different patterns. For instance, Austria demonstrates a moderate level of environmental crimes, with a balanced distribution across

all four categories. Belgium appears to have a relatively low incidence of environmental crimes, potentially influenced by its smaller geographical area. Similarly, Croatia shows a relatively low frequency of such crimes, which could be attributed to effective environmental policies or underreporting. Denmark exhibits a low to moderate level of environmental crimes, likely due to its strong environmental regulations. Conversely, France stands out for its high frequency of environmental crimes, particularly concerning the trade of protected species, possibly due to its diverse ecosystems. Hungary shows a moderate level of environmental crimes, with a balanced distribution across categories. Italy is a recurring area of concern on all the maps, suggesting a frequent occurrence of various environmental crimes. Overall, the study result highlights the critical environmental challenges facing by Italy and France, which need targeted interventions at both national and international (meso and macro) levels.

Figure 4 showcases a range of environmental offenses (x) from 14 European Union nations, vividly illustrating the substantial risks that environmental pollution poses to ecosystems and human well-being (calculated by using Eqs. 3 and 4). Italy leads with the highest rate (x_i) at 22.3%, followed by Sweden at 21.9% and Denmark at 19.8%, while Hungary, Slovakia, and Slovenia exhibit the lowest rates at 0.6%, 0.4%, and 0.3% respectively. Industries are major contributors to this macro-level problem, releasing pollutants into the air, water, and soil, highlighting the crucial need for proper enforcement of environmental regulations. Effective enforcement is essential to mitigate this issue, alongside promoting sustainable practices and incentivizing the adoption of clean technologies within industries to help decrease pollution levels.

However, a significant micro-level crime is improper waste dumping, which is causing soil, water, and air pollution. Italy leads the way in this category with a whopping at 54.4%. Belgium follows closely behind at 18.3% and France comes in third place at 10.8%. Conversely, countries like Croatia, Sweden, and Poland have minimal illegal waste dumping issue, which is below 2%. To keep the trend at minimum level governments should employ stricter penalties for offenders and increasing surveillance in waste dumping zone. Public awareness campaigns can also educate communities about how to dispose and recycle waste properly.

The meso-level crime is illegal trade of protected species, which is poses a major threat to the biodiversity. In this category France has the highest rate of crime rate at 27.2%. Slovakia (16.3%) and Belgium (9.6%) are second and third position. In contract, Austria (0.1%) and Croatia (0.2%) exhibit the lowest involvement in illegal trade of protected species. To fight back against wildlife trade crime international cooperation, strengthen law enforcement, and stricter regulations are essential. Additionally, helping communities to find alternative livelihoods can help to reduce their dependence on illegal wildlife trafficking.

A macro-level EVC is degradation of natural resource, like cutting down trees (deforestation) and overfishing is an alarming issue. Under this crime level France is substantially contributing at 32.6%. However, Sweden (23.4%), Norway (13.2%) and Denmark (9.7%) following behinds with comparatively less involvement. On the other hand, Austria (0.1%) and Slovenia (0.5%) has the lowest rates of resource degradation. However, to preserve our ecosystems need sustainable management practices such as planting new trees (reforestation) and creating marine protected areas.

The connection between population growth and EVC focuses on the social dimension of sustainability. The Fig. 5 depicts the connection between environmental crimes (X) and

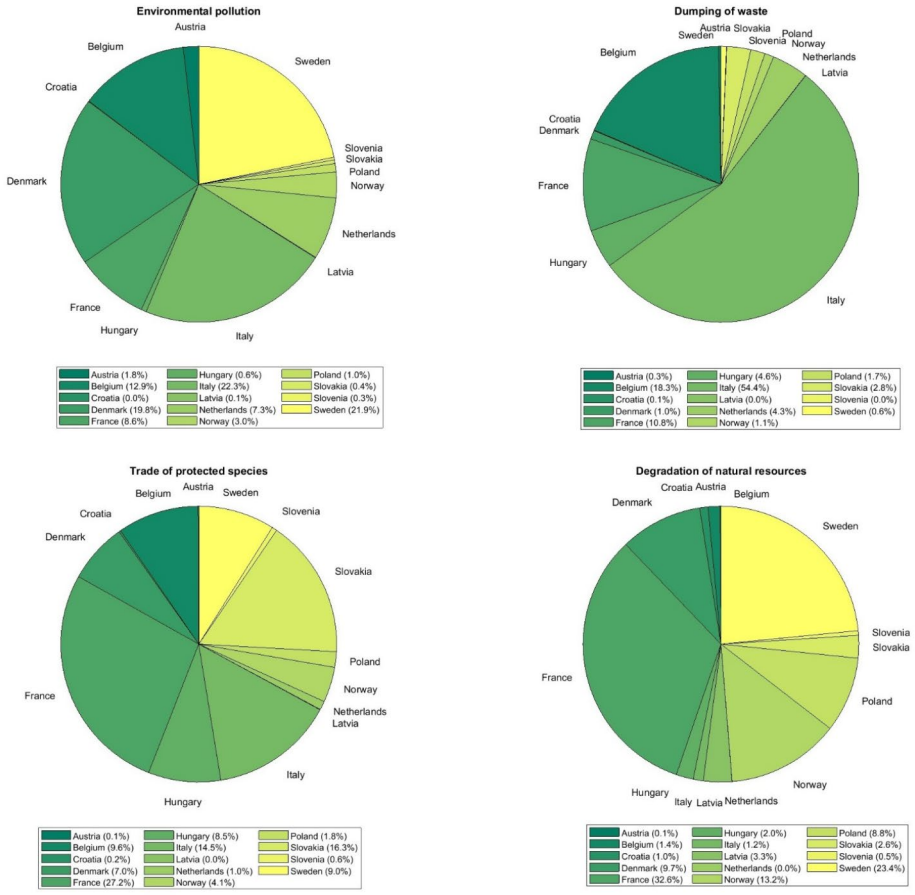

Fig. 4 Comparison of environmental crime ratios across fourteen European countries

population growth rates (Y) across 14 EU countries (calculated by using Eqs. 5 and 6). The best-fit trend line ($coefficientb$) represents overall trends for each country. The strength of these correlations measured by using the coefficient of determination $\left(R^2\right)$, which provides insight into the proportion of variance in the poverty ratio explained by changes in environmental crimes.

In terms of Environmental Pollution, a noticeable positive correlation $(b > 0)$with population growth is observed, indicating that countries with faster population growth tend to experience higher pollution levels. However, it's essential to account for other influencing factors. It is evident that the growth of the population is stable in regions where the number of crimes is less than 500. However, in areas where the number of crimes exceeds 1,000, there is a discernible but slight upward trend.

Regarding waste disposal, a negative correlation $(b < 0)$ is evident, implying that countries with lower population growth rates tend to have more efficient waste management. While the relationship appears to be relatively flat for regions with fewer than 1,000 crimes, the data reveals a significant decrease in population growth when the number of waste-

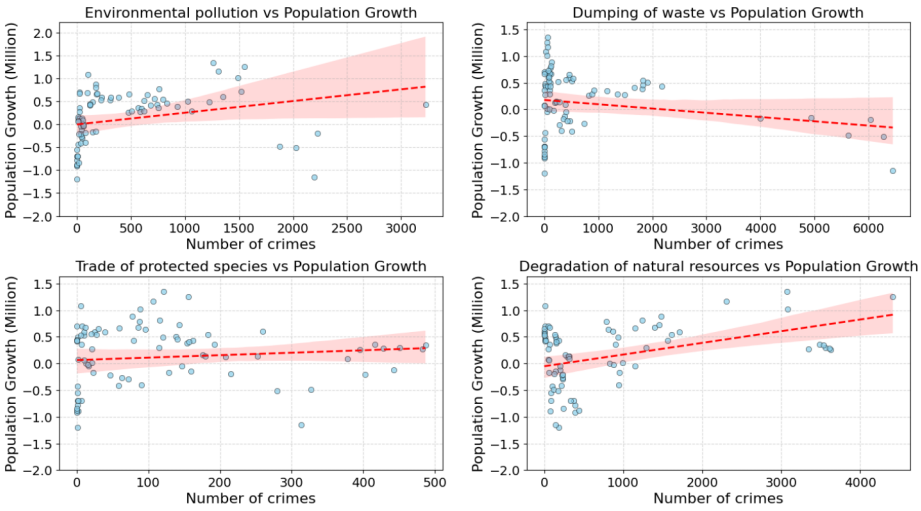

Fig. 5 Relationship between environmental crimes (X) and population growth rate (Y)

dumping incidents exceeds 2,000. This may indicate that an increase in waste dumping could result in environmental degradation to such an extent that it would impede population growth.

For trade in protected species, although the data points are scattered, there's a weak positive correlation $(b > 0)$, suggesting that countries with moderate population growth rates might experience higher levels of protected species trade. In the majority of regions where crime rates are below 200 incidents per 100,000 people, population growth remains relatively consistent, with slight fluctuations of between 0 and 0.5 million people. However, this correlation is weak, and other factors likely play a more substantial role.

Analysing natural resource degradation reveals a positive correlation$(b > 0)$ with population growth, indicating that countries with higher population growth rates facing significant natural resource degradation. This connection highlights the possible stress that a growing population could put more pressure on the environment's resources depletion. Nevertheless, the relationship is not particularly significant, as population growth remains largely unaffected in regions where the number of crimes reported is less than 1,000.

These findings highlight the complex link between EVC and population growth. However, further research is necessary to understand the mechanisms behind these connections. As a result, researchers are inclined to investigate any connections between multidimensional poverty ratios and environmental crimes in Fig. 6.

Figure 6 reveals a complex link between EVC and poverty ratio (calculated by using Eqs. 5 and 7). This connection highlights the economic dimension of sustainability. However, the relationship between environmental pollution and poverty demonstrating a weak positive correlation $(b > 0)$. As the percentage of the poverty ratio tends to rise, the environmental pollution rises along with it. However, the number of environmental crimes ranges from 0 to around 3000, while the poverty rate remains relatively constant between 12.5% and 30%. This correlation arises from the negative impacts of environmental degradation on land and water productivity, which impacting the agricultural activities and livelihoods.

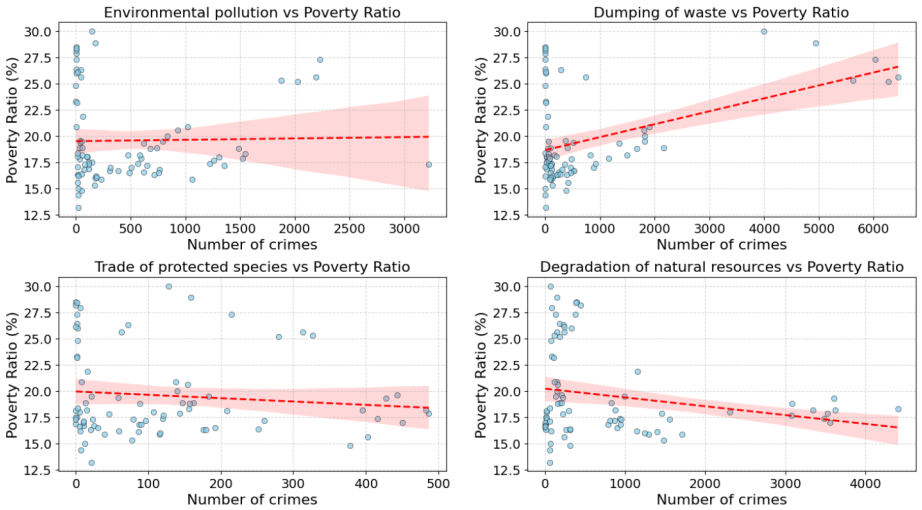

Fig. 6 Relationship between environmental crimes (X) and poverty ratio (Y)

Furthermore, Impoverished and underprivileged people often living polluted or environmental degraded areas. Consequently, high level of pollution makes people sick, resulting in less productivity and income loss.

Similarly, the improper waste dumping shows a significant and positive correlation $(b > 0)$ with poverty ratios. This is indicating that nations with higher poverty levels tend to experience higher illegal waste disposal. As the number of waste dumping crimes increases, ranging up to 6000 incidents, the poverty ratio tends to rise as well. In contrast, concerning trade in protected species, a weak negative correlation $(b < 0)$ with poverty ratio is observed. The number of crimes here ranges from 0 to around 500, with a slight negative correlation. This trend showing that moderate poverty rates tend to have a decrease trend in illegal wildlife trafficking. This unusual trend might involve eco-tourism, sustainable harvesting of natural resources, or created a new market for local crafts or products for income generation. Also, might be contributing the government support to help people by providing training, resources, and microloans for transitioning to new livelihoods.

Likewise, the depletion of natural resources demonstrates a substantial negative correlation $(b < 0)$ with poverty ratio, although the trend is somewhat obscured by scattered data points. The number of crimes extends to around 4000, and although the regression line shows a slight negative trend, suggesting that higher crime rates may coincide with a reduction in the poverty rate, the correlation remains weak. This indicates a correlation between the intensification of natural resource degradation and an increase in the poverty ratio. Impoverished individuals may bear a disproportionate burden of residing in polluted or degraded environments, lacking the means to relocate to cleaner areas.

Discussion

The incident of macro-level environmental crimes presents substantial obstacles to the sustainability of regions and communities, exerting an impact on multiple dimensions of their social, economic, and environmental welfare. The initial variable, environmental Pollution is a macro-level EVC. However, Italy (22.3%), followed by Sweden (21.9%) and Denmark (19.8%) are the most severely affected countries. As far as the EU is concerned, Italy (54.4%), Belgium (18.3%), and France (10.8%) are all responsible for illegal waste disposal. Aligned with this concern, Abdulai et al. (2024) examine the role of community engagement in mitigating illegal waste dumping within the EU. Their research suggests that fostering community engagement can demonstrably improve waste management practices and consequently reduce illegal dumping, thereby promoting environmental sustainability. However, the authors emphasize that successful implementation necessitates effective communication and collaboration among local authorities, communities, and waste management companies.

The fourth variable is the depletion or degradation of natural resources, which is also falls under the macro-level EVC. The current study identifies major countries, such as France, Sweden, and Norway, as contributors to environmental deterioration, which in turn presents sustainability challenges related to macro-level crime. Aligning with this notion, Rabbi & Amin (2024) investigate the potential of the circular economy to address resource depletion and promote sustainability within the EU. Their research suggests that the circular economy, emphasizing resource efficiency and waste reduction, can contribute meaningfully to sustainability goals. However, they acknowledge that a substantial shift in production and consumption patterns, coupled with supportive policies, is necessary for a successful transition to a circular economy.

These crimes can lead to irreversible damage and the loss of biodiversity. Various environmental crimes can jeopardise the sustainability of a region or community. Moreover, these crimes encompass air pollution resulting from industrial activities, water pollution caused by the discharge of urban and industrial wastewater into rivers, inadequate setting in urban waste management practices, and soil pollution arising from the introduction of toxic substances and construction waste (Naghavi, 2019). In a related study, Nadiri et al. (2024) and Rabbi et al. (2022) investigate the potential of renewable energy to reduce environmental pollution and promote sustainability in the EU. They argue that transitioning to renewable energy could significantly decrease greenhouse gas emissions and air pollution, thereby contributing to sustainability. Furthermore, EVC commonly referred to as green crimes, incorporate many illegal activities such as air pollution, water pollution, deforestation, and wildlife trafficking. These are significantly contributed to the depletion and deterioration of the natural resources (Masud et al., 2018). Another concern is terrorism's impact on environmental sustainability. Terrorist activities lead to rise in carbon dioxide (CO_2) emissions (Çetin et al., 2019). The EVC, incarceration, and improper foster care system having detrimental effects on communities and families. This makes it harder to transition towards sustainability and building a stable society in the long run (Tahir et al., 2022).

Furthermore, meso-level factors play a big role in biodiversity loss. These includes the trading protected species, wildlife, and plants, unregulated fishing practices, and the unlawful disposal, and irresponsible dumping of garbage and chemicals. These activities significantly impacting France (27.2%), followed by Slovakia (16.3%) and Belgium (9.6%),

which have significant implications on the environmental pillar of sustainability. Acknowledging these EVC highlights the urgent need for coordinated action to tackle these problems effectively. A recent study by Kaulen et al. (2023) explores the potential of technological advancements, such as blockchain and DNA tracking, to combat wildlife trafficking within the EU. The study suggests that these technologies could significantly enhance traceability and transparency throughout the wildlife trade chain, ultimately contributing to sustainable practices. However, the authors emphasize that the successful implementation of these technologies' hinges on international cooperation and the establishment of robust regulatory frameworks.

A major meso-level environmental threat at the regional and community level excessive grazing, which cause damage to grassland and land degradation. These two threats influence by population growth and increased pressure on land use (Hussein et al., 2022). Additional environmental threats encompass potential risks to public health, intentional deforestation, and unpermitted infrastructural development (Naghavi, 2019). Besides, the presence of organised crime has detrimental effects on various aspects of development, such as health and wellbeing, violence and conflict, governance, and the rule of law, as well as livelihoods and the environment (Reitano, 2018). Furthermore, it has been shown that terrorism exerts a detrimental effect on the environment sustainability by contributing to the escalation of CO_2 emissions. Conversely, trade openness and urbanisation have been identified as factors that exert a positive influence in this regard (Tahir et al., 2022). The widespread occurrence of environmental crimes at a regional level creates difficulties to achieving sustainable development. These crimes directly negatively impact the community's well-being, and the social pillar of sustainability.

The micro-level EVC can endangers the sustainability of a small community. This study identified improper waste dumping is the primary micro-level crime that contribute to environmental degradation. Among selected 14 EU countries, Italy (54.4%) is the most significantly contributing to this micro-level EVC. Besides, Belgium (18.3%) and France (10.8%) also struggling with this issue. In addition, illegal logging, and improper dumping of hazardous waste are on rise in some EU regions (Jonescu et al., 2023). A lack of strong regulation and enforcement are letting this EVC rise (Sarino et al., 2023). To tackle this problem, governments in each EU country should impose stricter punishments for environmental crimes.

However, it is important to see how these 14 EU countries punish for environmental crimes. Are their penalties strong enough to make people think twice before committing the EVC? Table 2 presents the fines and imprisonments for the four selected environmental crimes.

Analysing penalty data (Table 2) for environmental offenses across 14 EU nations reveals several significant findings. There is considerable diversity in the fines and imprisonment terms imposed for environmental offenses. Some countries, like Belgium, Italy, and France, have notably higher fines and longer imprisonment terms, indicating a stricter enforcement stance. In contrast, others have more moderate penalties. Interestingly, there is some consistency in the maximum fines imposed across different types of environmental crimes within each country. In addition to fines, some countries allow offenders to complete community service or participate in work programs if they can't afford to pay the fines. Though EU countries might enforce environmental laws in different ways, but these penalties show that they share a commitment to environmental protection.

Table 2 Penalties for environmental crimes in EU

Country	Environmental Pollution		Dumping of Waste		Trade of Protected Species		Degradation of Natural Resources	
	Fine	Imprisonment	Fine	Imprisonment	Fine	Imprisonment	Fine	Imprisonment
Austria	Up to €36,340	Depends on the circumstances	Up to €30,000	Up to 6 months	Up to €36,340	Up to 3 years	Up to €36,340	Up to 3 years
Belgium	Up to €1 million	Up to 5 years	Up to €500,000	Up to 5 years	Up to €1 million	Up to 5 years	Up to €1 million	Up to 5 years
Croatia	Up to €200,000	Up to 3 years	Up to €1 million	Up to 3 years	Up to €2 million	Up to 5 years	Up to €200,000	Up to 5 years
Denmark	Up to DKK 10 million (approx. €1.34 million)	Up to 4 years	Up to €2 million	Up to 2 years	Up to DKK 10 million (approx. €1.34 million)	Up to 4 years	Up to DKK 10 million (approx. €1.34 million)	Up to 4 years
France	Up to €750,000	Up to 7 years	Up to €75,000	Up to 2 years	Up to €750,000	Up to 7 years	Up to €750,000	Up to 7 years
Hungary	Up to HUF 20 million (approx. €57,000)	Up to 2 years	Up to HUF 50,000,000 (approx. €125,000)	Up to 3 years	Up to HUF 20 million (approx. €57,000)	Up to 2 years	Up to HUF 20 million (approx. €57,000)	Up to 2 years
Italy	Up to €1 million	Up to 6 years	Up to €50,000	Up to 2 years	Up to €1 million	Up to 6 years	Up to €1 million	Up to 6 years
Latvia	Up to €70,000	Up to 4 years	Up to €30,000	Up to 3 years	Up to €70,000	Up to 4 years	Up to €70,000	Up to 4 years
Netherlands	Up to €820,000	Up to 6 years	Up to €1 million	Up to 6 months	Up to €820,000	Up to 6 years	Up to €820,000	Up to 6 years
Norway	Up to NOK 10 million (approx. €1 million)	Up to 3 years	Up to NOK 10 million (approx. €1 million)	Up to 6 years	Up to NOK 10 million (approx. €1 million)	Up to 6 years	Up to NOK 10 million (approx. €1 million)	Up to 3 years
Poland	Up to PLN 1 million (approx. €227,000)	Up to 5 years	Up to PLN 1 million (approx. €230,000)	Up to 10 years	Up to PLN 1 million (approx. €227,000)	Up to 5 years	Up to PLN 1 million (approx. €227,000)	Up to 5 years
Slovakia	Up to €331,939	Up to 8 years	Up to € 350,000	Depends on the circumstances	Up to €331,939	Up to 8 years	Up to €331,939	Up to 8 years

Table 2 (continued)

Country	Environmental Pollution		Dumping of Waste		Trade of Protected Species		Degradation of Natural Resources	
	Fine	Imprisonment	Fine	Imprisonment	Fine	Imprisonment	Fine	Imprisonment
Slovenia	Up to €41,000	Up to 5 years	Up to €40,000	Depends on the circumstances	Depends on the circumstances	Up to 3 years	Depends on the circumstances	Up to 5 years
Sweden	Up to SEK 10 million (approx. €920,000)	Up to 4 years	Up to €30,000	Up to 6 months	Depends on the circumstances	Up to 4 years	Depends on the circumstances	Up to 2 years

Source (Bekendtgørelse Af Lov Om Miljøbeskyttelse Senere Aendringer Til Forskriften, 2024; Hungary - State of the Environment Report, 2019; European Justice, 2014; FAO, 2021; Geographical, 2024; GOV. SI, 2024a; Library of Congress, 2010; Lovdata, 1998; Mesić, 2007; Nature Vards Verket, 2024; République Francaise, 2024; Reuters, 2023; slovensko.sk, 2021; UNODC, 2023; VIA IURIS, 2019)

Conclusion

It is evident that environmental crimes like pollution, waste dumping, illegal trade in protected species, and degradation of natural resources are significant concerns in EU. These crimes manifest at various levels such as from individual actions to organizational practices and even international activities. Countries like Italy and France exhibit higher levels of environmental pollution, while waste dumping is more prevalent in Italy and Belgium. France appears to do a bit better on that front. However, France's involvement in illegal wildlife trade has risen concerns. In addition, Slovakia and Sweden also contributing to this EVC. Additionally, France also faces issues with the degradation of natural resources. Similar challenges are faced by Sweden, Norway, Poland, and Denmark.

The research findings also demonstrate that population growth, poverty ratio, and environmental crimes are interconnected. The results showed that as populations grow $(b > 0)$, there's more environmental pollution, trade in illegal wildlife, and damage to natural resources. Conversely, waste disposal showed a negative correlation $(b < 0)$ with population growth. Furthermore, the study also found that poverty played a role. When poverty was high $(b > 0)$, there was more pollution and waste. But in contrast, impoverished areas had less trade in protected species and less damage to natural resources. This could be because poverty-stricken communities have fewer resources to exploit or participate in illegal wildlife trade.

The researcher proposes different strategies and policies to combat environmental crimes such as pollution, illegal dumping, trade in endangered species, and resource destruction. These approaches target individual (micro), corporate (meso), and large-scale (macro) levels to effectively address these issues.

At the individual level (micro level), tackling environmental crimes means we need to educate and raise awareness. Educating people about the consequences of their actions helps them to understand the impact on the environment. Additionally, we need to encour-

age them to adopt sustainable habits like recycling and conserving resources to make a real difference. These efforts can play a crucial role in mitigating micro level crimes, particularly in regions like Italy, Belgium, and France. Furthermore, offering incentives like tax breaks, subsidies, or rewards can encourage people to adopt of eco-friendly practices. Getting community engagement through clean-up events and tree plantations can build a sense of responsibility to protect the environment. Businesses and organizations (meso level) also have great responsibility for combating against environmental crimes. They can adopt strong environmental management systems, making environmental concerns a part of their overall strategies through initiatives like corporate social responsibility (CSR), and by following regulation properly. Organizations should make accountable for their environmental damage activity and reward those who are practicing sustainability. Additionally, imposing stricter penalties for disobeying the rules and regulations can discourage organizations from breaking environmental laws. Environmental crimes are often driven by monetary gain. Consequently, utilizing the anti-money laundering legislation to target the financial dimensions of environmental crimes can curb the EVC at the meso-level. Furthermore, environmental reporting for corporation must be made mandatory, including but not limited to life cycle assessments, pollution data, and details on waste management. These policies can make a big difference to reduce environmental crimes at the organizational level, particularly in France, Slovakia, and Belgium.

To tackle EVC at the international level (macro level) all EU countries need to work together. This means agreeing on the same environmental rules, enhancing cross-border cooperation among law enforcement agencies, and strengthening international treaties. The EU can tackle environmental crimes by coordinating efforts to reduce environmental violation, sharing resources, expertise, and intelligence. Particularly Italy, Sweden, and Denmark need to take an integrated approach to tackle macro-level environmental crimes. This means taking action at individual, organizational, and international levels to protect our environment. This way we can ensure healthy environment and a sustainable future for everyone.

This research also highlights a major challenge to environmental crimes that threaten our environment, society, and economic well-being. To achieve a sustainable future, we need well-designed strategies. International cooperation, strong environmental law, and public engagement are essential to effectively combat these crimes. These efforts can create a balanced relationship between people and the environment.

This study helps governments, environmentalists, and citizens to take necessary action for a sustainable future. However, the study focuses on only 14 EU countries and might overlook the full picture of EVC within the EU. Regional variations and unrecorded environmental crimes could limit the study scope. It is important to acknowledge these limitations for precise assessments and understanding of the problems. Utilizing new technologies like satellite imagery, blockchain, and artificial intelligence for identifying, preventing, and addressing environmental crimes can consider as future research direction.

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Data Availability The data were used to support this article can be accessed at https://dataunodc.un.org/dp-crime-environment; and https://ourworldindata.org/population-growth#explore-datapoverty; https://ourworldindata.org/explorers/poverty-explorer.

Declarations

Conflict of Interest The author declares no conflict of interest.

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