CHAPTER 16

PERIVALLON: Improved Intelligence Picture and Operational Capacities to Combat Organised Environmental Crime

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Introduction

Environmental crime and, more specifically, organised environmental crime are identified as one of the key crime threats faced by the EU, being undeniably on the rise. As part of the EMPACT (2022–2025) priorities [1] and having a 5–7% yearly growth in number of offences [2], environmental crime has turned into one of the leading crimes on the European and global stage. Intentional dumping of polluting substances, illegal disposal of (hazardous) waste, (cross-border) illegal trafficking of waste and illegal trade of hydrofluorocarbons (HFCs) are examples of organised environmental crime. Such forms of crime can be challenging to detect and difficult to investigate by conventional means, highlighting the need for more sophisticated solutions enabling remote identification and

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evidence collection, as well as multimodal analysis and correlation of the information obtained. Moreover, significant disparities among Member States regarding the legal and judicial administration of different forms of environmental crime and their sanctioning, along with the lack of data and comparable EU statistics lead to an incomplete intelligence picture of organised environmental crime activities.

PERIVALLON aims to address these challenges by delivering an environmental crime observatory aiming to provide an improved and comprehensive intelligence picture of organised environmental crime and by developing an environmental crime detection and investigation platform at the forefront of technological innovation, while improving capacity building and international cooperation of security practitioners through enhanced investigation processes. Through this, the capacities of Police Authorities, Border Guards, and National and Regional Authorities will be improved by the means of extensive training, hands-on experience, joint exercises and testing of key technologies in relevant environments, boosting the uptake of

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the PERIVALLON technological stack. To this end, the application of PERIVALLON capabilities will be validated in four transnational operational demonstrations, including one EU Agency, as well as authorities from Italy, Greece, Belgium, Sweden, Romania and Moldova.

Second section describes the "Environmental Crime Observatory" and the approach carried out to obtain an improved intelligence picture of organised environmental crime. Section "PERIVALLON Technologies" describes the PERIVALLON platform's high-level architecture and its main components. Section "Conclusions" presents the main conclusions and next steps ahead.

Environmental Crime Observatory

The aim of the environmental crime observatory is to provide an improved and comprehensive intelligence picture of organised environmental crime activities across Europe, the modus operandi of such criminal organisations and networks, both online and offline, as well as comparable EU statistics regarding such types of crime. The goal will be to reveal the different push, pull and facilitating factors in order to provide a more sophisticated picture of the drivers and motivations behind environmental crime. An overview of applicable legislative and judiciary structures, the type of enforcement action, and its effectiveness on the local, national and European level will also be delivered.

Therefore, a holistic approach has been developed which includes desk research, along with questionnaires to relevant stakeholders (e.g., police authorities, border guards, environmental regional and national authorities/agencies, think tanks, NGOs, etc.), as well as to the society at large, with data obtained through the analysis and correlation of available data sources, such as EUROSTAT databases and relevant online sources. To get a comprehensive understanding of the criminological phenomenon, five research clusters have been created:

(i) *Cluster 1: Academic research.* Analysis of scientific papers and handbook articles, such as articles on Green Criminology and Transnational Organised Crime published between 2015 and 2022.
(ii) *Cluster 2: Reports.* Analysis of reports, such as the EUROPOL report on 'Environmental Crime in the Age of Climate Change' (2022) [3], the IPEC report on 'Environmental Crime in Europe' (2015) [4] and the EUROPOL report 'Serious and Organised Crime Threat Assessment' (SOCTA) (2021) [5].

(iii) *Cluster 3: Police Authorities, Border Guards and Regional and National Authorities.* Survey with the stakeholders in the cluster to learn more about the impact and the challenges of environmental crime (e.g., organisational, technological, knowledge and skills) on the law enforcement level.
(iv) *Cluster 4: Legislation.* Analysis of the existing legislative and judiciary structures and bodies on environmental crime on the European and national level.
(v) *Cluster 5: Former EU-funded projects.* Analysis of the results of former EU-funded projects, such as EFFACE [6] and AMBITUS [7].

The outcome of this research will support policy recommendations and inform the development of the PERIVALLON platform that will enhance investigation processes and methodologies. The results will be used to implement decision-support processes and to facilitate a continuous monitoring and review of the current landscape of environmental crime activities in Europe.

Some of the key challenges on addressing environmental crime described in academic research, as well as in reports by relevant authorities include the following characteristics: (a) victimless, (b) grades of invisibility, (c) 'low risk–high profit'. These three characteristics reflect the 'nature' of environmental crime. Does 'victimless' mean that water, air, earth, and soil, as well as climate, flora and fauna are not victims in a classical sense of human victims who are able to report an offence? Does 'invisibility' mean that damages caused by environmental crime acts are 'often part of an accumulative process' that is not 'immediately visible' [4]? In addition to that, environmental crime activities can be very profitable and less risky for offenders—shaped by low detection rates and low sanctions. These characteristics of environmental crime create challenges for the investigation processes and call for further developments of technologies detecting incidents at an early stage and decision support tools to identify different levels of risk, harm and types of causes.

One idea stemming from academic research is to use the 'conceptual framework for environmental horizon scanning' [8] as a tool to assess and analyse risks and harms. Although environmental crime is complex in nature and its consequences on human and non-human health are difficult to measure, PERIVALLON also aims to focus on the impact on the social level. These frameworks will thus be considered to perform the analysis that will inform the development of the PERIVALLON technologies, discussed next.

PERIVALLON Technologies

PERIVALLON starts with approximately 28 components, most around TRL 5 (technology validated in relevant environment) and aims to deliver them in TRL 7 (system prototype demonstration in operational environment). These components will be integrated to build a unique platform providing a single-entry point for the end users: the PERIVALLON platform.

PERIVALLON Platform

The PERIVALLON platform integrates a collection of components to a single-entry point delivered to end users that exploits the latest advancements in artificial intelligence (AI) in the fields of geospatial intelligence, remote sensing, online monitoring and multimodal analytics for combatting organised environmental crime. As described in Fig. 16.1, the PERIVALLON platform builds upon the concept of multidimensional integration of heterogeneous multimodal sensor data.

The capabilities of the PERIVALLON platform include automatic detection of waste disposal and pollutants on land and water based on

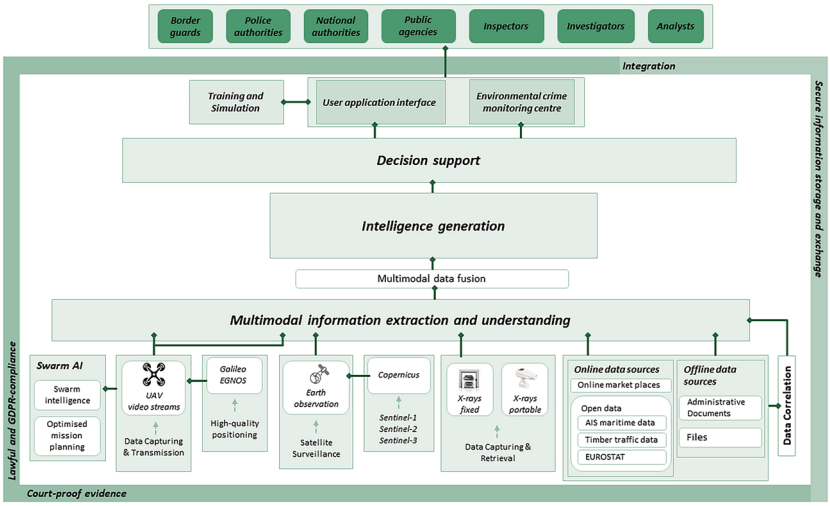

Fig. 16.1 PERIVALLON platform architecture

satellite imagery, optimal inspection and characterisation of sites of interest based on imagery captured by (swarms of) Unmanned Aerial Vehicles (UAVs), optimised X-ray scanning of concealed objects, multimedia-multilingual online content monitoring and analysis, maritime routes prediction, pattern recognition, real-time risk assessment, predictive analytics, audit trail and secure evidence collection and exchange, and holistic situational awareness.

Multidimensional integration of multimodal sensor data, ranging from satellite images, video streams from cameras mounted on UAVs, to information gathered from publicly available online sources and related administrative documents, is at the core of the PERIVALLON platform. Through the analysis and correlation of such multimodal information, the platform will provide explainable decision support to all relevant security practitioners towards detecting, investigating and preventing environmental crimes. Moreover, international cooperation and secure evidence collection will be established through improved data sharing and blockchain technologies.

Additionally, the PERIVALLON platform will provide a secure and user-friendly interface that will allow relevant stakeholders, such as law enforcement agencies, environmental organisations, government bodies and researchers, to seamlessly exchange information, insights and best practices. Furthermore, interactive dashboards and visualisations will present complex information in a clear and intuitive manner. This will empower users to gain valuable insights, make informed decisions and effectively communicate findings to stakeholders.

AI-Based Geospatial Intelligence, Remote Sensing and Scanning

Geospatial Intelligence is the discipline that exploits Earth Observation to enhance territory monitoring, e.g., to detect garbage dumped violating waste management laws. PERIVALLON exploits Geospatial Intelligence by designing, implementing and validating a pipeline for territory monitoring that exploits both remote sensing images, such as the ones collected by the Copernicus satellite constellations, and also images acquired at a short range by means of UAVs. The objective of the use of Geospatial Intelligence in PERIVALLON is to aid environmental agencies, Police Authorities and Border Guards in scanning the territory to detect clues of such criminal activities, such as illegal waste dumping in land and water.

Artificial intelligence and computer vision techniques are used in the design of supervised image processing models for detecting waste items in land and pollutants in water, as shown in Fig. 16.2. This requires the construction of Deep Learning components trained with images annotated by experts with a binary label (waste/no waste) and other information (e.g., the type of material and storage container); a relevant image dataset has

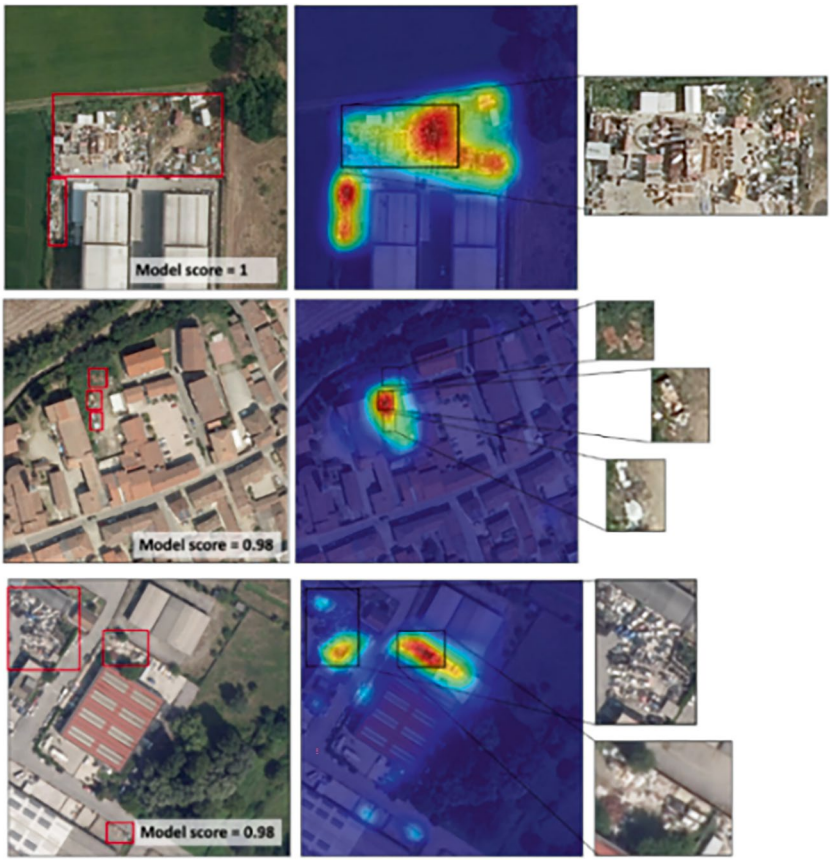

Fig. 16.2 Examples of waste detection in remote sensing images by a Deep Learning model: images annotated by the detector with the confidence value (model score) about the presence of waste (left); images overlaid with Class Activation Maps that highlight the region where the detector has found waste (centre); zoom on the regions of interest containing waste dumps (right)

been made public [9]. The detection approach consists of building binary classifiers for discriminating suspicious sites and multi-label classifiers able to recognise the type of materials. Such a scalable and semi-automatic approach enables the fast detection and prioritisation of sites where the investigation should focus, thus saving time and optimising operations.

Next, short-range images are acquired in UAV missions, with the aim of mapping the terrain in 3D, classifying the type of the visible materials more precisely, also exploiting the European waste codes as categories [10, 11], and quantifying volumes and growth rates. UAV mission management exploits advanced flight control techniques enabling the coordination of drone swarms for better site coverage and evidence acquisition, addressing such challenges as obstacles and no-fly zones.

Finally, the use of computer vision and AI also tackles the analysis of X-ray images, such as those acquired in marine ports and customs, in search of illegally transported materials, such as, for example, containers of ozone-depleting gases. This task required the development of yet another family of image-processing models, coping with the specific characteristics of X-ray imagery.

Online Monitoring for Environmental Crime Detection

PERIVALLON's online monitoring capabilities for detecting environmental crimes encompass several crucial components that work in synergy, as illustrated in Fig. 16.3. These components are designed to acquire

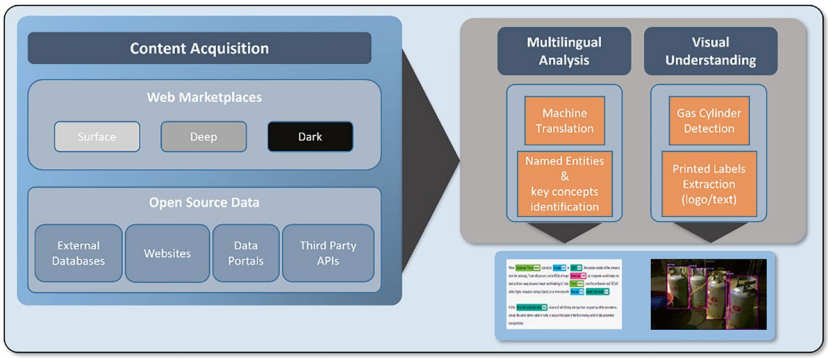

Fig. 16.3 The diagram illustrates the seamless integration of content acquisition, multilingual analysis, and visual understanding components

pertinent content (left), conduct multilingual analysis on the collected information (right), and employ advanced visual understanding (right) techniques to detect potential indicators of environmental crime. Here, we provide a detailed description of each component:

(i) *Content Acquisition*: The PERIVALLON platform employs robust content acquisition components to collect relevant information from diverse data sources. These sources include Surface/Deep/Dark Web marketplaces, external databases, data portals, websites and third-party APIs. Specifically, it focuses on detecting activities such as the production and sale of forged documents, illegal trade of ozone-depleting substances and HFCs, and dissemination of advertisements related to local illegal dumping areas. Continuous monitoring of identified pages, rapid relevance classification of posts, metadata extraction and periodic updates from waste crime data sources ensure the platform proactiveness.

(ii) *Multilingual Analysis*: Leveraging state-of-the-art machine translation techniques, multilingual analysis components enable semantic understanding of collected multilingual textual data. They automatically identify Named Entities and key concepts, disambiguate and resolve co-reference issues associated with concepts and entities, and enhance semantic understanding through online lexical resources. By conducting a comprehensive multilingual analysis, the platform identifies potential indications of environmental crime across languages.

(iii) *Visual Understanding*: PERIVALLON leverages advanced visual understanding components to detect and recognise objects of interest within images and videos collected through the content acquisition process. By employing cutting-edge computer vision techniques, the platform focuses on detecting and recognising gas and/or oxygen cylinders that may be associated with HFC trading. Furthermore, it categorises the identified cylinders as disposable or refillable, providing valuable insights into the nature of the trade. AI algorithms are utilised to extract textual information and logos from the recognised objects, offering additional indications of the potential illegal trading of HFCs.

Maritime Traffic Monitoring for Vessel Route Detection

The *Automatic Identification System* (AIS) is extensively used in the maritime world for the exchange of navigational information between AIS-equipped terminals. PERIVALLON partner MarineTraffic owns an extensive global network of AIS terrestrial receivers that capture vessels within coastal ranges at any given time, complemented by satellite AIS data for areas beyond coastal range.

In the scope of PERIVALLON, vessel mobility data reflected in the AIS-transmitted signal will be used in order to develop data-driven models for representing commonly sailed sea routes, as depicted in Fig. 16.4. The underlying algorithms will leverage vast collections of historical AIS data in order to derive maritime traffic statistics at a fine-grained spatial granularity. The underlying modelling methodology will focus on accurately extracting 'origin to destination' connections and their spatial characteristics at a global scale automatically, without the reliance on any additional information sources (e.g., nautical maps) or a priori knowledge. To this end, the implemented algorithms will succeed in overcoming big data challenges that pertain to huge volumes of uncertain data and transform them into representative models of vessel traffic patterns.

Subsequently, these patterns will be used in order to furnish the PERIVALLON platform with route prediction capabilities and will also serve as the basis of normality upon where deviations may indicate

Fig. 16.4 Container Vessel Routes in the Gulf of Guinea

abnormal sailing behaviour. The resulting routes will reflect typical voyages per different vessel categories and will focus on voyages connecting European ports with sub-Saharan African areas of interest, where organised operations of electronic waste smuggling are commonly carried out. Additional gap-filling mechanisms for vessel route reconstruction via vessel detection in satellite imagery will be employed in order to compensate for information loss in cases where vessels cannot be detected via AIS, for instance in cases of intentional AIS switch-off performed by the vessel crew during illicit operations.

Intelligent Decision Support & Secure Information Management

With the ultimate goal of supporting earlier, informed and optimised decisions of security practitioners, the PERIVALLON platform includes Intelligent Decision Support and Secure Information Exchange capabilities that work in an integrated fashion. The related components are developed to (i) perform real-time risk assessment of criminal activities, (ii) identify patterns and trends in multimodal data, (iii) make predictions to anticipate short- and long-term risks, (iv) monitor and analyse environmental crime activities through user-friendly interfaces and (v) store and exchange multiple evidence types with full auditing and chain of custody features.

In particular, the related components are the following:

(i) *Multimodal Fusion and Risk Assessment*: PERIVALLON platform performs the ingestion and transformation of the diverse geospatial, remote sensing, scanning and online data via an ETL (Extraction, Transformation and Loading) process. Based on the insights extracted by the geospatial intelligence (Section "AI-Based Geospatial Intelligence, Remote Sensing and Scanning") and online monitoring (Sections "Online Monitoring for Environmental Crime Detection" and "Maritime Traffic Monitoring for Vessel Route Detection") components, as well as available historical data, a risk assessment module supports the practitioners in the identification, evaluation and prioritisation of criminal activities. Dynamic risk assessment processes, triggered by the assessment of impact and probability of occurrence, formulate optimised mitigation strategies.

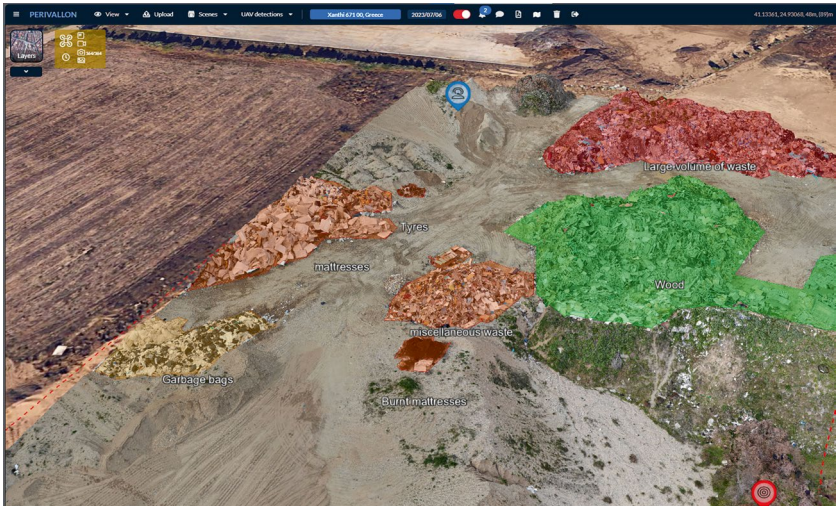

Fig. 16.5 Monitoring and analysis of different waste disposal sites on land in the Environmental Crime Monitoring Centre

(ii) *AI-Based Pattern Recognition and Trend Detection*: Leveraging the diverse multimodal data containing spatio-temporal information, computationally efficient AI algorithms are used to reveal hidden correlations, detect irregularities and identify data trends. The component provides red-flag indicators about environmental crime activities and is capable to adapt to the ever-evolving modus operandi of criminal behaviour.

(iii) *Predictive Analytics*: PERIVALLON also develops a proactive approach to crime prevention by exploiting multiple sources of information, such as previous cases, EUROSTAT data, and socio-economic factors, combined with information extracted by tools developed within PERIVALLON to effectively forecast future crime events.

(iv) *Environmental Crime Monitoring Centre*: A user-friendly dashboard will allow practitioners participating in the investigation to better exploit the available information through the geolocation and representation of results of waste detection and visualisation of real-time monitoring, as illustrated in Fig. 16.5. After the analysis, the practitioner will be able generate a report with selected pieces of evidence.

(v) *Secure Information Management, Audit Trail and Evidence Exchange*: The diverse data are stored in a secure database allowing full auditing and chain of custody, alerting the user in case of unusual access patterns. Furthermore, a blockchain-based system provides secure and reliable data exchange between the authorities involved in assessing the evidence of the crime.

Conclusions

This paper introduced the main expected results from the PERIVALLON project, with a key focus on the environmental crime observatory and the main technological components of the integrated PERIVALLON platform, thus presenting an approach to improve the current intelligence picture and initial findings about key factors describing organised environmental crime activities across Europe. Furthermore, the main technological components were described taking into account the provided improvements on the operational capacities of security practitioners. As the project evolves, the work described in this paper will be implemented, demonstrated and evaluated by the practitioners, aiming to provide long-term benefits on their daily practice.

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