Illegal dumping investigation: a new challenge for forensic environmental engineering

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Abstract

When Italian law enforcement investigates illegal environmental dumping, data must be carefully compiled, analyzed, and validated in order to successfully prosecute the parties responsible. Investigators must be able to produce a validated data-set construction using recognized scientific methods such as random sampling. Chemical/physical analysis, photographs and/or other data with significant details must conclusively demonstrate the pollution source and causal connection between the pollution and observed environmental damage.

Authorized officers appointed by the Prosecutor Office to exercise their functions under technical consultant supervision have extensive powers of investigation in relation to illegal dumping. There are a number of investigation tasks that can be carried out at both the place the waste was dumped ('on-site') and in the office/lab to catch and deal with offenders. This paper introduces the use of advanced technologies (special aerial platforms, innovative application of thermography and advanced software tools) and new methods and procedures to detect and fight this illegal activity. This is the first known use of these methods in both the fields of environmental research and law enforcement. This paper provides an example of where law enforcement and university research teams can collaborate on developing enhanced environmental protection methods. The proposed procedures, techniques and technologies, were tested and validated in environmental police actions directed by the Italian Prosecutor Office and allowed us to understand the forensic value of the environmental engineer.
Keywords: thermography, illegal dumping, law enforcement.

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1 Introduction

Environmental crime can be defined as comprising acts or omissions which directly or indirectly damage the environment and which constitute a breach of legislation [1]. When the environment is harmed, there is not necessarily immediate damage to the life, health or property of specific persons. Very often the consequences of pollution appear indeed in a different place or a long time after the polluting act has been committed. Control of the territory is a necessary action for the identification and also the prevention of such environmental issues. Data on environmental crime are obtained through complaints received by police forces or through reports from inspections and investigations carried out by authorities. But the extent of unreported environmental offences is considered extremely high. It is a difficult challenge to perform long-term environmental monitoring with today's standard methods, especially using advanced and/or not conventional technologies because of vehicle, cost, and mission limitations. Moreover where there are small sources of pollution and contamination over a wide area, it is very difficult to detect only with ground-based tools. In this paper we discuss the employment of new technologies (effective combinations of platforms and sensors), exceeding the current limits of traditional methods of detection. Judicial police detectives and university research teams of forensic environmental engineers have collaborated using the proposed method in the specific case study of an illegal landfill.

2 Investigated scenario

The scenario of our case study is an illegal landfill (fig. 1), discovered in the middle of a street in Campania region (Italy), during a mission in collaboration with Italian State Forestry Corps.

Figure 1: Aerial photo of illegal landfill, located in the middle of a street in Campania region (Italy).

In this site mixed and undifferentiated materials/wastes (rubber, plastic, glass, ceramic, metal, paper, electronic components, etc.) were found "open air" (fig. 2). Moreover, this landfill is close to an industrial area and not so far from several urban areas.

Figure 2: Details of the illegal landfill of fig. 1.

3 Materials and methods

Key point of the proposed method is the combined use of remote and proximal sensing; indeed, they are excellent tools to monitor wide areas with accuracy and quickly.

In our mission we tested several platforms (fig. 3) and specific sensors (fig. 4).

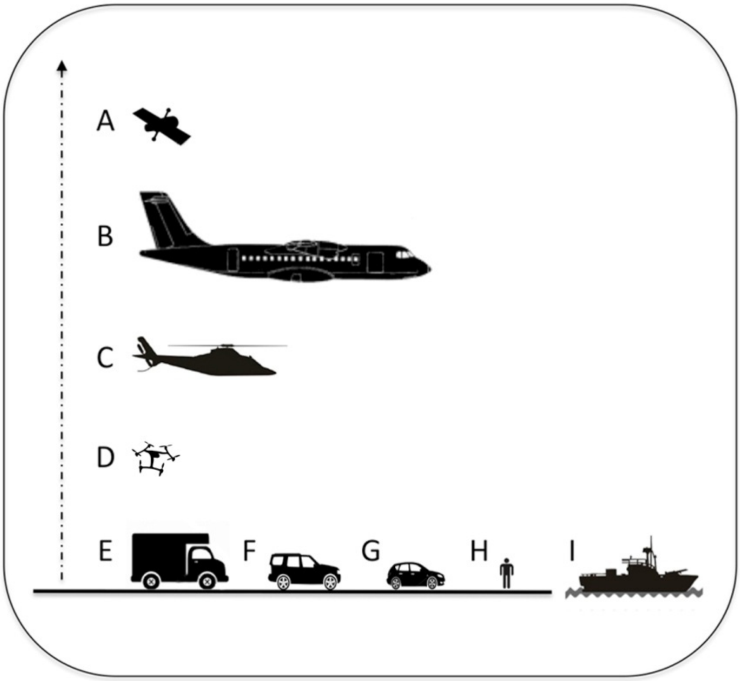

Figure 3: Platforms scheme, segmented by quote and environmental matrix (air, land, water): A) satellite; B) airplane; C) rotorcraft; D) drone; E) mobile lab; F) off-road vehicle; G) car; H) "human" operator; I) boat.

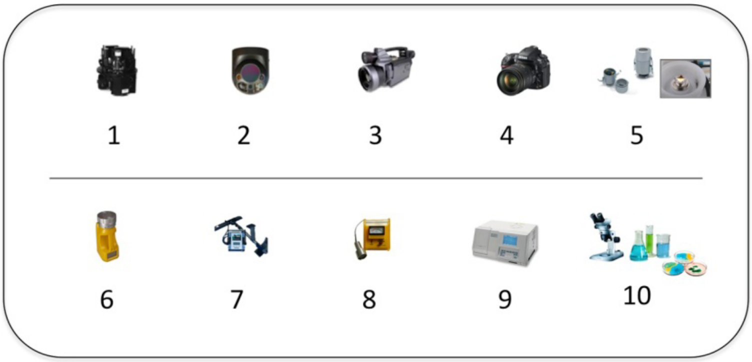

Figure 4: Main sensors/payload devices: 1. multispectral/hyperspectral; 2. CCD TV + IR; 3. IR radiometric; 4. DSLR camera; 5. air-pollution real-time sensors; 6. air sampler; 7. magnetometer; 8. geiger counter; 9. spectrophotometer/spectrometer; 10. chemical/physical/micro-biological tools.

Among electro-optical sensors we consider the thermal sensor a key technology to discover environmental anomalies/criticalities.

A thermal sensor detects radiant energy from a surface target, heated through radiation, convection and conduction; because of this, it is quite difficult to get an accurate measure of absolute temperature of an object using only this method but, it is possible, with high accuracy, to detect the difference of temperature between two or more object/spot in the same IR thermal image [2]. The intensity of emitted radiation is dependent upon the nature of the surface of the emitting material. An object which is a perfect emitter at all wavelengths is known as a black body. Imperfect emitters by definition emit less radiation than a black body at the same temperature. To express the extent of imperfection of an emitter the material is given a value which expresses its ability to emit radiation as a proportion of that possible at the same wavelength by a black body. This value is known as the emissivity (ε). In real life most bodies are neither grey nor black and the emissivity is dependent on the wavelength of radiation being considered [3]. The surface characteristics which govern emissivity allow us to univocally identify a body exploiting its thermal behaviour.

Moreover, it is possible to carry thermal sensor on the aerial platforms, increasing in this way its effectiveness.

The advantages of using aerial platforms are represented mainly by:

- the increased field of view with the result of being able to patrol large areas quickly;
- the ability to reach areas otherwise unreachable;
- the coolness of the matrix we are investigated;
- a quick display of the extension of the survey phenomena;
- operator safety who doesn't have to be exposed directly to the risk of contamination.

The specific platforms and sensors/payload that we used in this case study are reported in table 1.

Table 1: Platforms and sensors/payload used in the case study discussed in this paper.

PLATFORMS		SENSORS/PAYLOAD									
		1	2	3	4	5	6	7	8	9	10
A	•										
B											
C	•			•	•						
D	•			•	•						
E	•										•
F	•										
G	•										
H	•			•	•						•
I											

To demonstrate IR aerial system capabilities, a recent mission, for environmental contamination in the Campania region of Italy is presented. This search, which was performed in cooperation with the Italian State Forestry Corps, consisted of two different air vehicle flights (fig. 5):

- a medium altitude scan, using a manned rotorcraft (AW109) and an electro-optical payload (IR camera SC660/T 620);
- a low altitude scan, using an unmanned autonomous drone (StillFly) and an electro-optical payload (several environmental sensors including a mini IR camera).

Figure 5: Shots grabbed during the flight mission in the Campania region of Italy. In the two shots on the right the helicopter and the drone fly together.

As the vehicle platform changed from the helicopter to the unmanned rotorcraft, the flight altitude was decreased, which consequently increased the resolution. The increase in resolution revealed environmental "micro-anomalies" along the illegal landfill.

4 Results and discussion

This paper introduces the use of advanced technologies (special aerial platforms: drones/UAS etc., innovative application of thermography and advanced software tools) and new methods and procedures to detect and fight illegal activities. This is the first known use of these methods in both the fields of environmental research and law enforcement.

Each figure of these results is the output of a complex process that begins with the raw-data acquired by the on-board sensors and concludes with a complete graphical and numerical report (including geo-referencing, matrix analysis, data-fusion, graphs, 3D models, etc.). In this paper, the IR data-fusion, colour pictures, graphs and 3D textured models are presented to demonstrate this new approach.
In detail:

- using specific software we built a quality textured 3D models from HD still images (fig. 6–7);
- analysing the 3D model with a 3D CAD software it was possible the sizing of the illegal landfill and the computation of surfaces and waste volumes (fig. 8);
- using FLIR Researcher software we analysed the radiometric data to discover criticalities in the wastes (e.g. fires) (fig. 9);
- using a 3D CAD software we combined IR texture image and 3D model (fig. 10–11).

Finally, with the geographical reference of the discovered illegal landfill, we perform a risk analysis computing the distances of the waste area from the urban areas in the investigated scenario (fig. 12).

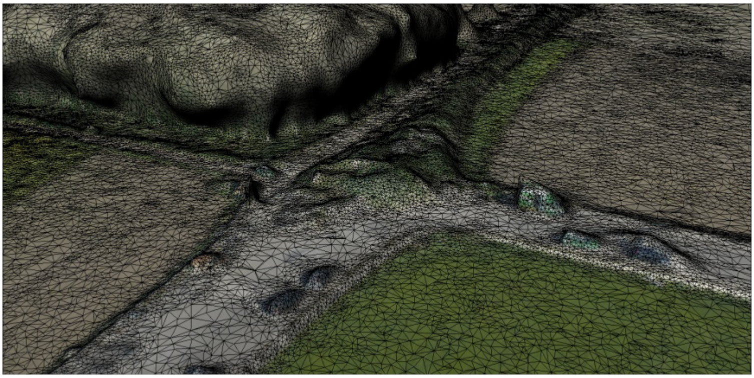

Figure 6: A detail of a 3D reconstruction of the illegal landfill.

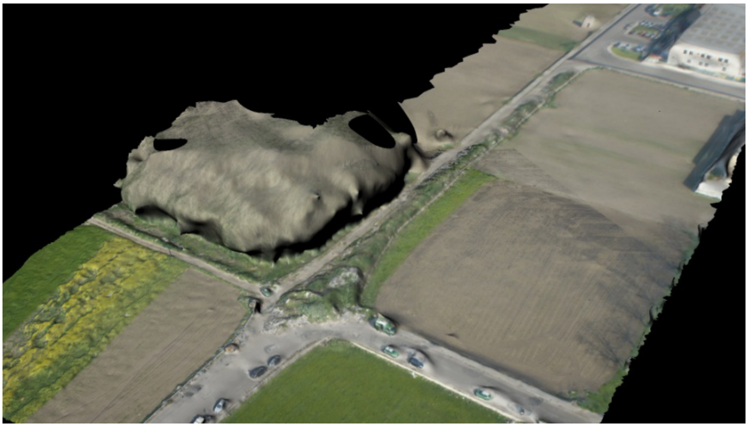

Figure 7: 3D textured polygonal model of the illegal landfill.

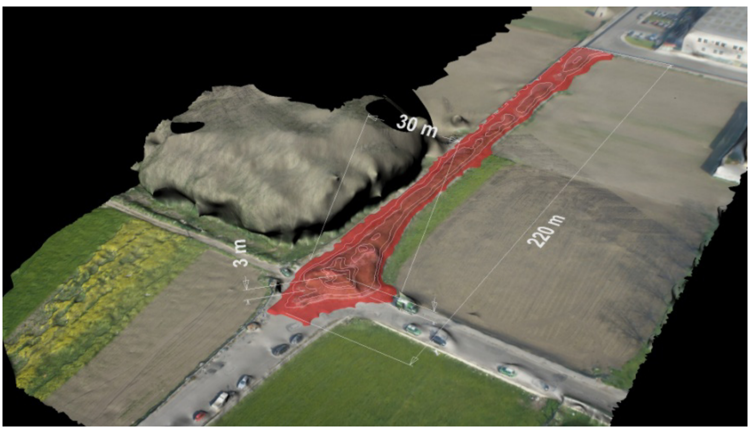

Figure 8: Illegal landfill sizing, computation of surfaces and waste volumes.

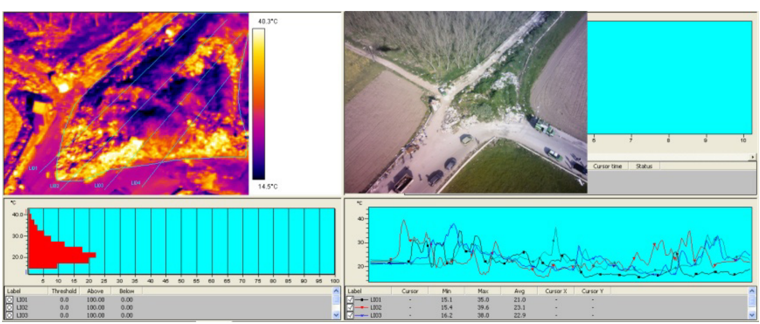

Figure 9: Example of analysis of IR radiometric output.

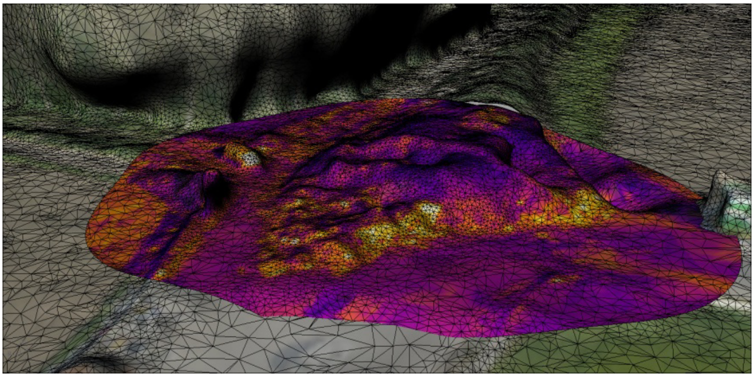

Figure 10: A detail of IR radiometric output /3D polygonal model overlap

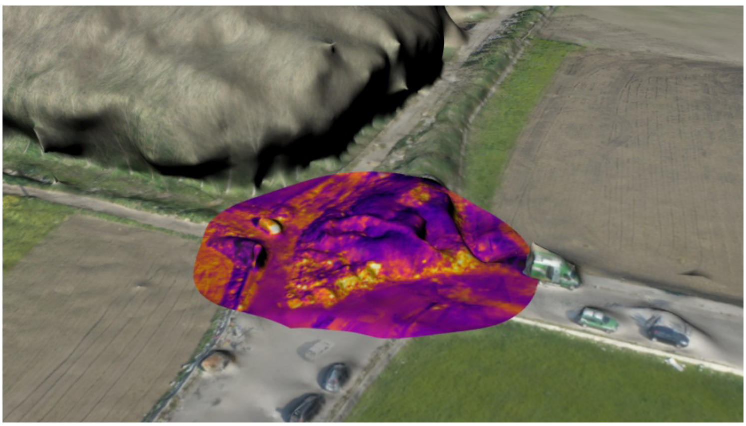

Figure 11: Combined IR radiometric output/3D textured polygonal model of the illegal landfill.

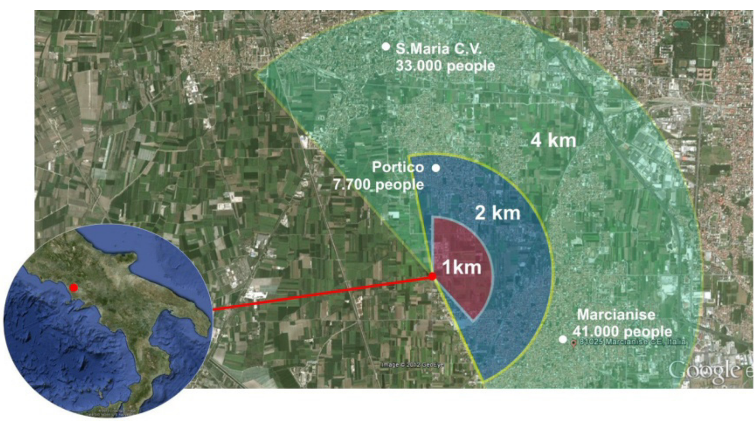

Figure 12: Geographical reference of the discovered illegal landfill and analysis of the distances from the urban areas.

5 Conclusions

Offenders of environmental crime face a low risk of detection and prosecution; this is partly linked to insufficient resources specialized to detect the environmental crimes. This paper introduces new methods and procedures to detect and fight this illegal activity.

The main novelty of this research lies in the specific procedure that involves standard and advanced aerial platforms (e.g. drone/UAS), aerial infrared thermography, specific information technology tools and combines the data collected at different altitudes with those grabbed by standard methods.

Moreover, this paper provides an example of where law enforcement and university research teams can collaborate on developing enhanced environmental protection methods.

The proposed methods could serve an attorney's case well in situations involving issues deriving from contaminated soil, water or air.

Finally, today's experienced environmental engineer has had to acquire a working knowledge in a wide variety of other disciplines such as toxicology, public health, ecology and/or other environmental sciences as well and, moreover, grew in its capacity to keep abreast of newer technologies and adapt existing technologies to new challenges. Thus, to understand the forensic value of the environmental engineer in the environmental field, it is important to highlight that this engineering role requires such broad knowledge of related areas and a validated problem solver capability.

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