


# Forensic Geoarchaeology in the Search for Missing Persons

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**Abstract:** Despite widespread concern over missing persons, there has always been little clarity on what the word “missing” means. Although the category of young runaways is, indeed, an important cluster, other popular concepts related to disappearances describe a portion of missing persons. Thus, the following question persists: What exactly does “missing” mean? In this brief communication, we would like to open a discussion about the social phenomenon of missing persons and the consequent deployment of people and techniques to find those persons. In particular, the benefits of some forensic geoarchaeological approaches that are not yet fully standardized will be highlighted, such as geographic profiling and the use of multispectral satellite images, in order to provide materials for future searching protocols.

**Keywords:** forensic archaeology; missing phenomenon; geographic profile; multispectral satellite images

## 1. Introduction

Each year, thousands of people disappear all over the world, but little is known of their stories, especially regarding what those people did while they were away from their homes, loved ones, and previous lives [1].

While much attention is given to missing children who are lost or kidnapped while attempting to escape their parents’ control and why older youth run away, much less attention is paid to adult disappearances since free will in adults is always presumed in the absence of obvious reasons for suspicion at the time of reporting [2].

The world of the disappeared is heterogeneous; it includes people living on the margins of society and also those who feel that their life holds no significance. Some of these people choose to disappear, while others are forced to do so. Unfortunately, few studies report the views of the missing, explore their motivations and experiences while they are away, consider under what circumstances they return, or mention any episode of contact with the people they leave behind. Although some cases get significant media attention due to the circumstances of the disappearance or the missing person’s age, most disappearances are experienced in silence by the missing person’s families [2,3].

The phenomenon of disappearance is not easy to define. On the surface, it may look like a matter of will—i.e., the person wanted to disappear. This suggests a deliberate interruption of contact with one’s partner, parents, children, and siblings and a deviation from one’s routine. However, this definition does not include doubtful cases or those where the factor of intention can be ruled out with certainty. Some missing persons may be kidnapped, some may experience an accident, and some

may become lost due to conditions such as dementia, which severely affects a person's ability to make rational decisions. Some of these individuals, however, do not even consider themselves to be missing at all; rather, they consciously choose to change their lives by escaping from abusive relationships, running away from home, etc. Missing persons and those who report those persons as missing may think differently about the situation. Labeling the missing persons as passive victims may also portray them as individuals with little autonomy or awareness of the choice they have made [4].

Besides rare exceptions, the police implicitly recognize that disappearing or wanting to remain missing is a right. For adults, exceptions are given for people certified as incapable of self-determination, those being given mental-health care/treatment, and those wanted for a crime before disappearing. At any time, people can be presumed to be missing by others, whether or not they consider themselves to have disappeared. These persons may be registered as missing by relatives or friends or by relevant healthcare or other similar service providers. Similarly, people can disappear under uncertain and possibly risky circumstances without anyone reporting them as missing—for instance, when a juvenile becomes homeless after being thrown out of his/her home by close relatives or runs away to avoid abuse at home [5].

Within the general context of forensic sciences, forensic geoarchaeology is a scientific discipline that uses geoarchaeological theory and methodologies in a legal context to localize, document, and interpret geographical, ecological, pedological (soil), and osteological finds, as well as patterns and traces at a crime scene, enabling the development of a chronologically ordered sequence of natural and human activities [6–9]. Forensic geoarchaeological casework involves the support of law enforcement for remote sensing possible crime scenes (with the help of satellite images, GIS, geographic profiling, and geophysics), locating missing and presumably clandestinely buried human remains or objects, mapping and recovering human remains and associated finds, supporting humanitarian investigations and mass fatality events, investigating human rights violations, controlling exhumations of bodies with conventional burials at regular cemeteries, and protecting archaeological heritage from looting, trafficking, and damage [6,7].

There is now a wide range of forensic methods that have the potential to assist law enforcement personnel in their investigations of missing persons, for both those presumed alive and those presumed dead. Both criminologists and criminalists make a significant contribution to the search for missing people, their recovery, and the gathering of relevant information. In cases of missing persons, police investigations are, of course, compelled by legal constraints, and risk assessment informs the scope and applicability of the investigation. Normally, under the direction of an investigative team, police can use various techniques and tools during the search (such as psychologists, air support, search dogs, and water search teams). The search covers a variety of tasks, including physically checking for the home address, searching for the missing location, checking for the person at acquaintances' homes, exploring known hangouts, analyzing transport options, and searching for virtual check-ins in the local area. Early searches are important for the distribution of intelligence and data that feed into the later sections of an investigation. Unfortunately, data on missing people can be scarce and unreliable. The drivers behind missing persons are difficult, and research has so far centered on why adults go missing from their everyday lives [1,2].

Despite substantial progress in the field of law enforcement and improving debates on police abilities, greater attention on crime has meant that there are still considerable gaps in our comprehension of missing people and, consequently, the seriousness of their disappearances. Here, relevant police procedures should be outlined. Of prime importance is the process of implementing two preliminary forensic approaches in an effort to improve information gathering in the very earliest stages of the missing persons search procedure [2,5].

It would be interesting to open a discussion about the social phenomenon of missing persons and the consequent deployment of people and techniques to find those persons. The role and potential of selected forensic geoarchaeological approaches could be applied independently from the definition of "missing" to quickly locate missing persons in early stages of the search. The benefits of these methods,

however, are not yet fully standardized, such as geographic profiling and the use multispectral satellite images. Standardizing such approaches would benefit future searching protocols.

## 2. Spatial Behaviors of Missing Persons

Geographic profiling, or locus operandi [10], is a continuously evolving criminological strategy with multiple scientific applications that vary with different cases. Furthermore, this method is constantly updated as its mathematical foundations are continually refined. Geographic profiling can be utilized and applied to handle the phenomenon of missing persons. However, there are few studies worldwide on the spatial behavior of the disappeared [10–16].

One variable to consider for the missing is their spatial behavior, a fact that can be deduced from the resolved cases in which people have been traced—dead or alive—to a specific place. Classifying this information would be relevant to optimize the efficiency of the activities of search teams/parties, both in terms of the number and quality of resources used to fulfill the primary objective of finding the missing person as soon as possible and to increase the chances of finding that person alive. Lists of missing persons are periodically created in many countries; these lists are classified based on gender, age, and certain categories (e.g., disabled, drug addicts, and people suffering from neurodegenerative diseases) [17].

One of these rare studies focused on police reports in large cities of the United States [14] and compared the disappearance data of both adults and minors. This research study showed that most missing persons were either found or chose to return to their homes within a week of their disappearance. However, it was also found that adults required more time to locate than minors.

On average, disappearances lasted about 10 days, and in almost one-third of the case studies, the disappearance took place in a public space or at a friend's house [12,17]. This basic information would be very useful in understanding the spatial behaviors of the disappeared. Resolved cases should be compiled in a report including geographic data pertaining to the location where the missing person was found and a comparison of this data to the region of the domicile or the last sighting to assess how far the person traveled, which can also be based on the person's chosen means of transportation.

The purpose of this process is to construct statistical behavioral models that can be applied to future cases with similar characteristics, thus providing search operators with a scientific toolset. Globally, police use geographic profiling as a predictive intervention-based tool to repress crime [18]. Just like this tool, the spatial behaviors of missing people could be used to identify priority search areas, which may shorten the search time [19].

The National Center for Policing Excellence has highlighting the importance of considering the behavioral patterns of missing persons since the first edition of their guide was published on behalf of the Association of Chief Police Officers (ACPO) in 2005. The ACPO data collection form accurately established the information that is essential to record. Since then, the ACPO has hoped that police forces would widely adopt this form to standardize their databases. A groundbreaking research study from 2003 on the spatial behaviors of disappeared persons found that 45% of these people moved to another region, 22% moved abroad, and 10% remained in the same city while being absent from their own homes. However, although this research is significant, it does not help in directing the relevant research resources because it does not mention the distances actually travelled by the disappeared persons and does not differentiate between adults and minors [2,11,15,16].

Identifying spatial behavior patterns is of the utmost importance, as this information can be used by law enforcement to detect the most likely areas of search. This information can help find missing people before they endure any physical injury and can also save precious police resources, funds, and time. Therefore, efforts to collect and document this sort of information as accurately as possible is a desirable venture in the future. Besides basic geographical information, such as the address of the missing person's residence or domicile, the place of disappearance, knowledge of whether the missing person has a mobile phone (and its number) or a mailbox, more extensive geographic information

should be collected when filing a missing person's report. Compiling such information (as shown in Table 1) with more precision is key [12,13,15–17].

**Table 1.** “Geographical” questions required to be asked to construct a geographic profile with related reasons.

Question	Motivation
<i>Where does the missing person usually go?</i>	This question aims to create a geographic database of the places the missing person usually visited (no matter how distant in terms of years/months or km—for occasions such as holiday destinations or out-of-region places). A runaway person (unless forced) tends to gravitate towards the areas they already know.
<i>What is or was their workplace or the place where they performed activities including volunteer work?</i>	As implied in the previous question, a person often follows current or previous routines. The workplace and places of any other routine activities of a missing person can be useful for geographic profiling.
<i>Where did any sightings (certain or alleged) or findings (of personal objects, means of transport, etc.) occur?</i>	Obviously, these pieces of geographic information have different levels of relevance (certain and alleged geo-information have different statistical “weights”). Analysis of this information is key for accurate predictions in terms of geographic profiling.
<i>Who the missing person most frequently and recently contact?</i>	This information may seem non-geographic but may help determine the missing person's network and, consequently, the possible positions of the person's most frequent and recent contacts through network analysis.

Traditional geographic profiling focuses on criminals and their hot zones, i.e., the areas where they are likely to commit crimes. In this circumstance, investigators start by searching the areas frequented by the missing person and their habits before the disappearance. Then, they predict the potential search area. Among other advanced mathematic calculations, basic calculations such as Voronoi polygons and Delauney triangulation, in combination with the distance formula and search for the centroid, are implemented [10]. These computational geometries define a series of scientific geographic techniques and quantitative measurements as objective elements that allow the analysis and interpretation of the pattern of points resulting from the various sites related to the disappearance. However, the validity of these measurements depends on the number of locations. Therefore, the validity strictly depends on the correct acquisition of the “geographical” items during the reporting phase [11].

This approach may drastically reduce the extent of the search area to a few square kilometers instead of the many hectares used in standard searches, which often yield negative results. Such an innovative and unique tool would revolutionize the search methodologies for missing persons in the preliminary steps by reducing costs, hazards, and stress on the rescuers and vehicles. This methodology would support law enforcement by making the search for missing persons more effective [10].

### 3. “Seeing the Unseen” with Multispectral Satellite Images

Another variable to be considered in disappearances is the possibility to use remote sensors to “see the unseen”. The satellites that orbit around Earth number in the thousands and have different purposes, both civil and military. Some of these satellites continuously take photos of the Earth's surface for different purposes (environmental monitoring, weather forecasting, urban expansion, security, etc.) [20]. Satellite images are acquired by sensors that capture images at non-visible frequencies. Indeed, the electromagnetic spectrum—the set of all possible frequencies of electromagnetic radiation—has lower frequencies (radio waves, microwaves, and infrared waves) and higher frequencies (ultraviolet, X-rays, and gamma rays) than the visible spectrum. These frequencies are not detectable by the human eye but only by specific sensors.

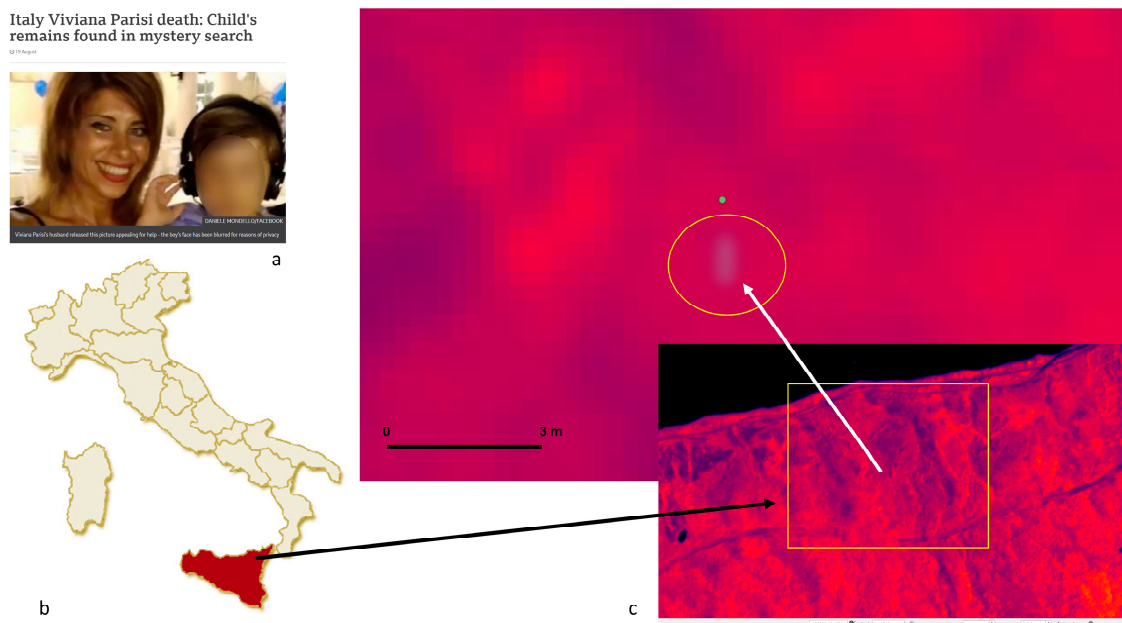
Infrared radiation (IR) is a spectrum that is particularly useful in remote sensing [21]. IR has a frequency band lower than the visible range but higher than that of radio waves. The wavelength

of this band is between 700 and 1 mm [22]. IR is used, for example, in night vision equipment for when there is not enough visible light. Infrared sensors convert incoming radiation into an image. This image can be monochrome (for example, warmer objects will be lighter), or a false color system can be used to represent different temperatures [23]. However, IR is also used in infrared spectroscopy to characterize materials [24–26]. This last use is fundamental in the forensic field and, in particular, in the search for missing persons [27–29].

The ability to detect human bodies is not simple due to the relationships between human bodies and other animal bodies. Thus, supplemental spectral data can considerably improve the detection capabilities of relevant systems. This sequence of actions requires the selection of suitable spectral signatures that uniquely define, and can be used to identify, human bodies. If the spectral signature is characteristic for each material and specific for each combination of reflections and absorptions of electromagnetic radiation at different wavelengths, then by analyzing the signatures at near infrared wavelengths, we can correctly identify human bodies [29,30].

This method was applied to identify the bodies of two people who disappeared in August 2020 in the Sicilian countryside in Italy. A mother and her son, following an accident on the highway, disappeared for reasons still to be ascertained, climbing over a guardrail, and vanishing into the countryside in the bushes near the highway. On the day of their disappearance, the search began, but this search was not successful. This search employed dogs, drones, and numerous rescue teams. Despite this search, the body of the mother was found 8 days after the disappearance and the body of the son 14 days after the disappearance, both considerably and clearly dismembered by the local fauna [31].

The satellite data downloaded later showed that near-infrared images acquired by satellites orbiting the area of the disappearance only 24 h after the accident on the highway had indicated anomalies related to the spectral signatures of two lifeless human bodies near the area where the mother and son were eventually found (Figure 1).



**Figure 1.** This figure shows the international media coverage of the Italian case (a) [31] the Italian region where the disappearance occurred (b); an NIR image of the area of disappearance with details of the anomaly related to the mother's lifeless body (c).

Thus, if this methodology had been used in a timely manner, the bodies would have been recovered before the local fauna disfigured them, which complicated the autopsy and made it very difficult to establish not only the cause of death but also the dynamics involved.



Notably, there are many factors that can affect a multispectral satellite analysis (resolution, footprint, availability, rate, cloud coverage, etc.). Moreover, modern technological improvements allow us to use both multispectral and hyperspectral sensors mounted on UAVs, but these sensors are very expensive. Indeed, the speed with which it is possible to find these multispectral satellite images and their low cost can contribute, sometimes in a decisive way, to the search for missing persons in the earliest stages of the investigation.

#### 4. Discussion and Conclusions

Disappearance is a sudden event for families and, in some cases, has no clear explanation. In the past, the only hope of resolution in such a situation was the spontaneous return of the missing person and the goodwill of the police in managing the search, relying primarily on the help of friends and relatives. Not every country has a specific body that deals with disappearances by coordinating and supervising police activities (e.g., Italy).

The alarming phenomenon of disappearances requires uniform operating procedures for the quicker and more efficient coordinated management of search operations. Missing person cases require laborious and meticulous investigations, for which preparation and patience are essential to gather useful elements that will lead to locating the missing person. Firstly, the feelings and reasons that induced the missing person to leave must be analyzed. In some cases, pathologies or the abuse of antidepressants may aggravate the person's health and lead to their departure. For this reason, the use of geographic profiling is of great importance in the search for missing persons and can be used to support rather than replace other, more traditional, search techniques.

The use of geographic profiling and multispectral satellite image analysis to handle the phenomenon of missing persons is currently considered an innovative, important, and useful methodology. By drastically reducing the search areas, these techniques can contribute to the rapid resolution of disappearance cases, which, unfortunately, are constantly on the rise in Italy and throughout Europe.

On one hand, the success of geographic profiling mainly depends upon highlighting the missing person's habits and routines, as well as the places that the person frequented and/or visited before their disappearance. Locus operandi is an investigative tool that can be employed for disappearances, kidnappings, serial rapes, serial killings, serial arson attacks, bank robberies, and bomb attacks. This tool helps research the places targeted by the victim and the perpetrator and can identify both the identified victim and the unknown offender as the potential location of a geographical region. This approach moves the inquiry toward the geographical data of the locations where the crime happened and gives the analyst a "priority area" where one can better utilize the necessary investigative resources. In addition, this tool gives general examples of the patterns of movement of both the victim and the perpetrator in the geographical space [18].

On the other hand, the success of multispectral satellite image analysis is related to the increasingly advanced technology available to everybody for defining the area that should be searched the most thoroughly.

Nevertheless, both approaches cannot be applied without adequate education of the operators and all the people involved in such analyses. Their relative affordability and availability should facilitate the wide diffusion of such methods. Knowledge and openness to accept improvements in this field, particularly at the national scale, is another crucial aspect of this problem, hindering sometimes the adoption of such improvements. However, the benefits of these methods in the earliest stages of the search can be standardized by implementing these techniques in national search protocols together with preexisting methodologies. These two techniques can be used to assist, on a case-by-case basis, other well-established methods, such as drones [32], Ground Penetrating Radar (GPR) [33], and man-trailing/cadaver dog searches (K9 searches) [2], to search for missing persons.

Due to their fast, precise, and non-destructive abilities to plan further forensic actions, such methodologies should be commonly used and regulated within the forensic geoarchaeological framework during all crime scene investigations.

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