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Greece - Republic of North Macedonia

Preven-T

PREVEN-T DELIVERABLE 1. Del. 4.3._ Innovative techniques to detect the existence of discontinuities in Axios river embankments due to mammalian action.

Authors:	Dimitrios Emmanouloudis
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PREVEN-T Project Profile

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Acronym:	PREVEN-T
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URL:	http://www.preven-t.eu/ - http://prevent.the.ihu.gr/ (NOT OFFICIAL - temporal)
Start Date:	03/03/2022
Duration:	18 months

Partners

	International Hellenic University (IHU)	Greece
	Military Academy "General Mihailo Apostolski" (MAGMA)	RNM
	National Park Pelister	RNM

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Version	Date	Author (Partner)	Remarks/Changes
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0.3	31/07/2023	Dimitrios Emmanouloudis (IHU)	2nd Draft ready for quality control
1.0	31/08/2023	Dimitrios Emmanouloudis (IHU)	FINAL VERSION TO BE SUBMITTED

Abbreviations and acronyms

Deliverable	D
Expected Outcomes	EO
International Hellenic University	IHU
Non-governmental organization	NGO
Land Use Land Cover	LULC

Executive Summary

PREVEN-T is a 18 month duration project funding from the Interreg IPA Cross-border Cooperation Programme: PREVEN-T – CN2 – SO2.4 – SC049.

The overarching objective of the PREVEN-T project is to improve the operational efficiency and the administrative capacity of relevant services in natural disasters management. At the same time project's goal is to enable education, awareness and sensitization of the local population, so that in cooperation with the competent authorities to have a coordinated action to deal with Natural and Technological Disasters and Risks.

The presence of badgers, porcupines, and foxes in the proximity of earthen embankments

causes the dig of tunnels and holes inside these structures (see Figure 1a) and result in altering external and internal geometry with different impact on their hydraulic performance and structural integrity. Landslide disaster risk might accordingly increase. Animal burrowing and possible interventions have not been sufficiently under the attention of the scientific literature for a long time. The relatively recent trend of wildlife and parks regulations, which aim to safeguard the huge natural heritage, might have allowed the spread of animal life close to human settlements, such as embankments, and the consequent damage to earthen structures with the concern about interventions.

Possible types of levee deterioration due to wildlife activities can be categorized into three main categories: structural damage, surface erosion and hydraulic alterations

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2.1 Research aims

2.2 Methodological framework

This deliverable (WP 4.3) deals with the detection of damage to the embankments due to the activities of wild animals, so that it is possible to repair them in time in order to reduce or even eliminate the risk of occurrence of flood phenomena, due to them.

It is well-known that a flood can affect the environment, the economy of an area and its society. Especially when they appear in areas with a large population and intense economic activities, the damage they cause is very significant. In terms of the environment, a flood can cause negative effects on the flooded soil (e.g. erosion) and make areas of arable land unproductive. The economic effects of a flood are divided into direct economic effects (e.g. destruction of real estate, agricultural land, production, infrastructure) as well as indirect ones related to the costs of restoring the infrastructure to a condition that can deal with possible similar of importance and risk flooding events in the future. In general, floods are responsible for 20-30% of economic losses and most deaths on the planet due to natural disasters. Therefore, the possibility of preventing a flood is a dominant issue for local self-government bodies, as well as for the central administration of each country.

One of the causes of flooding is the inability of the embankments to provide the required protection during the occurrence of intense weather events, due to the damage they have suffered from the activities of wild animals. Generally, levees are elongated natural or man-made barriers made of earth, usually located parallel to the course of a river or along a flat coastline. The main purpose of man-made levees is to prevent flooding of neighboring lands and to slow down natural changes in the course of a waterway. They are often found in areas where, due to the presence of water, there is highly developed vegetation and by extension rich wildlife. This results in earth dams/embankments being vulnerable to wild animal incursions causing damage to them

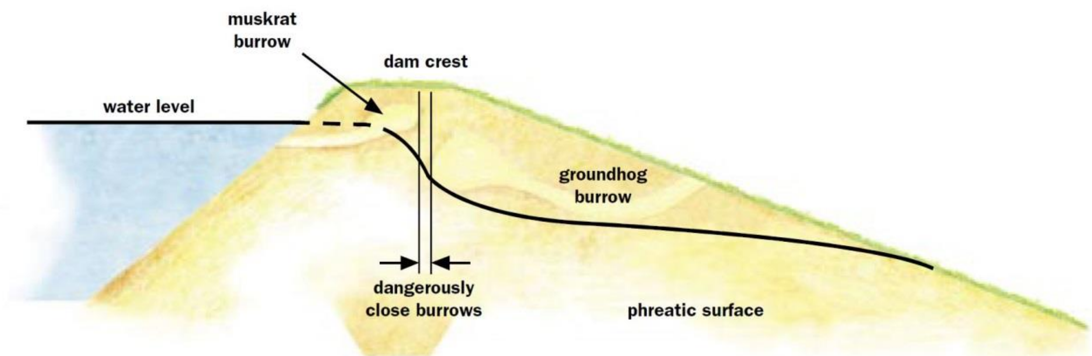


Figure 1: Animal barrows inside levees

More specific, some animals excavate burrows, tunnels and dens for shelter, while other predatory animals expand these burrows by digging in search of prey. In addition, quite often herbivores forage for the vegetation growing on the embankments, therefore soil retention on both the slopes and the crown of the embankment is not possible. These animal activities can create openings/holes on and within the dykes affecting their safety and behavior.

The main impacts from the above mentioned activities are: the destruction of the embankment structure, hydraulic changes and surface or internal erosions. Some of the above effects, such as surface corrosion, are easily recognized, while other effects, such as internal corrosion, may not be apparent or may only manifest after a considerable period of time.

Various methods have been applied to detect and evaluate the damage of the embankments due to wildlife activities, some of which are:

- Electrical Resistivity Tomography – ERT:
  In this method, the potential difference caused by the introduction of electric current into the earth through electrodes is measured. The measured potential difference reflects the difficulty with which electric current flows through the subsoil, thus giving an indication of the soil electrical resistance. Different geological formations also have different electrical resistivities. Knowledge of the geoelectric structure of the subsurface can be used to indirectly find the geological structure and locate structures of interest. It is a method widely used for the study of embankments and is of interest for the detection of conductive openings/holes which are filled with water or clay but not for empty holes.

  Advantages:
  - Suitable for time delay measurements.
  - High air resistance approaching infinity.
  - Soil morphology is not a limiting factor.
  - High resolution of results.

  Disadvantages:
  - The method can be disturbed by the presence of sheet piling, temperature and rainfall.
  - Setup labour-intensive and survey time intensive.
  - Expertise is required to interpret the results.

- Ground penetrating radar – GPR:
  This methodology is based on the emission of EM waves, which spread inside the ground and come back to the GPR timing unit as reflected waves, once they encounter changes in electrical properties of the materials constituting the subsoil. Generally, in geologic applications, GPR methodology performs excellent results when clean, coarsegrained materials such as quartz, sand as well as gravel occur, while in fine-grained soils such as silt and clays, its performance is limited mainly due to the presence of water. Ions dissolved in the water give rise to an electrical conduction mechanism. Hence, the more ions dissolved in the solution, the higher the conductivity. As a result, clayey soils impose a strong reduction of EM wave penetration inside the medium which limits the use of this methodology.

Advantages:

- Rapid and relatively cheap technology with high velocity of acquisition and possible to check the results directly during the data acquisition (fundamental in case of hydrological emergencies).
- Valid method for detailed study of the shallow part of embankments and for detecting local strong anomalies.

Disadvantages:

- The topography surface must be clean from vegetation and it is not possible to work with rainy weather or with the wet condition of the soil.
- As electromagnetic method lacks the resolution and depth penetration of resistivity surveys
- The maximum survey depth that can be reached is four to six meters compared to the height of the embankments which is usually between five and twelve meters (limited efficiency in checking the internal structure of the embankments).

This particular methodology was tested for its applicability in detecting animal burrows within the embankments, but was not effective, as the use of even a 100 MHz antenna was unable to detect small punctual targets (as deeper the target as higher must be the contrast in dielectric properties to produce any noticeable reflection), as well as due to the presence of moisture.

- Electromagnetic method – EM

EM is another method that gives an estimation of an electric property namely the conductivity of the subsurface. The method also provides an estimation of the resistivity, as the conductivity is its reciprocal.

Advantages:

- Its acquisition is more rapid and easier in surveying than resistivity measurements because no electrodes have to be inserted into the ground.
- Electromagnetic instruments can be attached to drones, which would be advantageous for difficult terrain.

Disadvantages:

- It is more subjected to cultural interference as electrical lines and metallic objects.
- It is quite noisy.

- Infrared thermography

Infrared thermography is based on the principle that any body with a temperature greater than absolute zero emits energy in the form of radiation in all directions. Thermography, or infrared photography, detects the emission of thermal radiation and results in a visual display of the thermal signal (thermogram). Thermography does not directly measure the temperature of a surface, but the change in surface radiation. Thus, subsurface defects in a material create local differences in surface temperature, which arise due to the different degrees of heat transfer in the zones where imperfections are present.

Advantages:

- It has a relatively low cost and has the ability to provide qualitative and quantitative information very quickly.
- Can be used remotely (on drones)

Disadvantages:

- This method cannot provide information on the internal structure of the studied structures (levees), since the maximum investigation depth is about a few centimeters.
- It is necessary to choose the correct time to do the investigation in order to have a correct lighting without shadow.
- Measurements cannot be done under rainy conditions or a too sunny weather.

- Muon Transmission Radiography- MTR

  It is a non-invasive method that uses rays composed of muons to explore the subsurface. Muons are elementary particles similar to electrons but with a mass 200 times larger. Muons are capable of penetrating deep into the Earth's crust for up to hundreds of meters, depending on their energy. While traveling through materials muon trajectories are continuously modified by very tiny amounts, because of random electromagnetic interactions with the positively charged nuclei, thus determining a possible non-negligible overall deflection of these particles from their original trajectories. The intensity of this effect is higher for low energy particles and increases with the atomic number Z of the traversed medium. When the traversed thickness is sufficiently large, the lowest energy muons can be definitively stopped, finally decaying into electrons, quickly absorbed inside the material, and neutrinos, which instead move away undisturbed. The consequent reduction of the muon flux intensity is the effect which is used in the MTR technique to provide information on the density distribution inside the material volume under investigation. In the case of embankment examination, the MTR technique is the only practically usable myographic technique and it is implemented by counting the number of muons that traverse the structure in front of the detector. Muon track angular distributions are measured only downstream of the volume of interest and later compared with similar measurements performed looking at a free portion of the sky, with the detector pointing in the same direction, in such a way as to allow an estimation of the directional muon transmission, defined as the fraction of muons that survives for each direction after traversing the target.

Advantages:

- MTR can be performed without removing the vegetation gowned up on the levee's top.
- MTR is influenced only by the materials' density variations and not by other environmental conditions (e.g. the subsoil saturation).

Disadvantages:

- For zenith angles larger than 90° the muon flux is practically null.
- The data acquisition time can be quite long (order of many weeks).

- The muon detector dimensions are strictly related to the size of the object to be visualized (the smaller the detector, the smaller the levee portion that can be investigated).
- To reconstruct the actual volumetric distribution of the burrow's measurements of the same portion of the levee from different angles are required.

- Unmanned Aerial System – UAS equipped with Light Detection and Ranging (LiDAR) and digital RGB (red, green, blue) camera
  LiDAR is a method of determining distances using lasers and measuring the time it takes for reflected radiation to return to the sender and is used to capture and digitize real-world objects in 3D and works through the following steps:
  - The laser scanner emits a laser at an object.
  - The laser interacts with the structure of the object and again returns to the device.
  - The scanner using a camera, as well as intelligent algorithms, measures the dose of the returned laser and calculates the position and structure of the object.

  Advantages:
  - Short data processing time.
  - Non-invasive nature of the measurement.
  - Possibility of frequent measurements at a reduced cost.

  Disadvantages:
  - Gives reliable information about "bare", unvegetated terrain.
  - It cannot be automated.

In this subpackage the techniques that have been chosen to be applied in order to evaluate their effectiveness in detecting the damage to the embankments due to the activity of wild animals, are infrared thermography, colorimetry and 3D laser scanning. In more detail, the methodology that will be applied includes the following stages:

1. Definition of a study area in river embankments where there is intense wildlife activity. The selection of the study area will be based on reports and observations of competent bodies/services (e.g. Forestry Department).
2. Identifying specific points on the embankments where they may have been damaged by wildlife activity. Initially, with the use of a thermal scanner that will fly integrated in a drone, the existence of mammals within the body of the dykes will be detected macroscopically. Afterwards, and once the initial identification is made and the presence of the mammals at the specific points is established, with the help of a gas chromatograph, an attempt will be made to confirm their presence and possibly their number. In addition, we mention that the thermal scanner helps in the initial detection, because it has the ability to detect large areas, while the detection of the chromatograph comes additively and confirms the first detection. It is noted that the chromatograph can only be used on a small, local scale, for this reason the initial macroscopic localization is done with a thermal scanner.
3. Investigation of the surface erosion suffered by the embankments using a 3D slope laser Scanner. This investigation is independent of the animal detection investigation, since in some cases mammals and dike disturbances may co-exist, but in others the mammals may have caused the disturbance and moved away, so their presence in the area of the disturbance does not exist.

4. Recording of the under 2. and 3. points on a map and informing the competent services for the maintenance and repair of the embankments in order to prevent possible floods.

The specific techniques were chosen mainly because they give immediate results and are relatively simple, without requiring special expertise from the user. The main goal is, if these are deemed effective, to be a useful tool for the responsible Local Government Services in order to be able to detect possible damage to the embankments in the future, to proceed immediately with their maintenance/repair and in this way to prevent possible floods.

The study area for this subpackage was a part of AXIOS river bed between Axioupolis and Polykastro. The selection criterium was the significance of this part of Axios bed, as far as it concerns agricultural and civil protection purposes, while there is a major presence of Mammalians.

Map of the entire research area

The animals that mainly provoked the problem and appear usually in the area of the embankments are foxes, wild boars, jackals, moles, badgers, European ground squirrels and myocastors.

For these animals, some information related to their lifestyle, reproduction, etc. was collected in order to correlate their presence with possible damage to the levees, which are summarized as follows:

- Fox (V.Vulpes):

Fox is a mammal belonging to the family Canidae. The most common and widespread species of fox is the red fox (Vulpes vulpes), whose fur is reddish. It is not an endangered species, but on the contrary its amazing adaptability has led to its wide geographical spread worldwide. The fox is an omnivore (it eats invertebrates, small mammals, nuts, fruits, insects, etc.). Its characteristic habit is to bury (usually with leaves, soil or snow) excess food for later consumption.

The breeding season of foxes in Greece starts from January to February. The Red Fox is mostly extremely active in May when she is raising her young. Then there is a greater chance to be seen even during the day. When breeding season arrives, the female digs a nest with labyrinthine passages within an area.

- Mole (Talpa europea):

The mole is a small mammal with very limited vision, but a highly developed sense of smell, and is adapted to a subterranean lifestyle. It lives in the fields and has nests a few meters below the ground.

- Badger (Meles meles):

The badger is a mammal belonging to the family Mustelidae. It builds its nest in sheltered places, which consists of a main burrow a few meters long with several small corridors, which cover the ventilation of the main burrow and also act as an emergency exit. It is nocturnal and forages at night. Its diet is very varied and includes insects, worms or other invertebrates, small mammals, reptiles, fruits and other plant material. Its breeding takes place anytime from late winter to mid-summer.

- European Ground Squirrel (Spermophilus citellus):

European Ground Squirrel is a small mammal with a tufted tail, a species of ground squirrel, a member of the rodent family. It feeds on seeds, roots, shoots, leaves and invertebrates. It is a diurnal animal that lives in colonies in areas with low grass, grassy embankments or crops. It builds its nest in the ground by digging deep burrows with many exits.

- Myocastor (Myocastor coypus):

It is classified as a rodent mammal of the myocastoridae family and looks like a huge rat. It lives around three to five years and is distinguished by its great reproductive capacity, as it can mate from the age of 4 months, while the female can give birth up to 3 times a year and up to 13 cubs each time.

It lives on the banks of rivers and lakes, in canals, in wetlands and in marshes of fresh, brackish and, rarely, salt water. It is a very good swimmer, but it also moves comfortably on land. It searches for its food mainly at night, while during the day it rests in burrows. It feeds on vegetation, not only aboveground but also on plant roots, and in that way, it creates bare patches on the ground with no trace of biomass, which disrupts the habitat of other animals. It gradually completely destroys the habitats of other animals, aquatic vegetation, marsh flora, erodes and eventually destroys irrigation systems, drainage works, river and lake embankments. It also feeds on agricultural crops, such as corn, rice, vegetables, wheat, barley, destroying them, but also on bird eggs that it finds in their nests on the ground, in reeds or floating in water, destroying their reproduction, resulting in birds leaving their permanent nesting areas. Ultimately, it destroys the flora of the area, displaces the local fauna, disrupts the balance of ecosystems and dramatically degrades the economic and environmental value of the areas in which it occurs.

- Wild boar (S.scrofa):

The wild boar is a forest species. It lives in the dense scrub forests of broadleaf, oak, chestnut and beech. But it often moves in search of food in swampy areas, in agricultural crops bordering forests or even at high altitudes in the summer. The wild boar is an omnivorous animal. It feeds mainly on acorns, chestnuts, various fruits and nuts, roots and bulbs which it takes out by digging the ground. It is a polygamous species. The estrus period starts at the end of December and ends at the end of January. The female for the birth, constructs a rudimentary nest and gives birth to the young.

- Jackals (Canis aureus):

The jackal is a medium-sized omnivorous mammal of the genus Kyon. The golden jackal can be found in Europe and Asia. In Greece it is an endangered species and is found mainly in Kerkini, Halkidiki, Fokida, Samos, Peloponnese, Attica and in Eastern Macedonia and Thrace. It feeds on garbage, fruits, plants and small animals such as amphibians, rodents and insects, and can also eat goats and sheep. It lives in densely vegetated areas for safe cover. It also uses ravines and wetlands with dense reed vegetation as its habitat, while it often enters inhabited areas. As nests it uses natural holes in rocks and gaps between the roots of trees, or nests of other animals such as badgers and foxes.

From the above it follows that all wild animals except for the jackal can cause damage to river embankments either by making nests or by digging to find their food. However, as there was no information from the above-mentioned services about the areas in which the presence of wild animals is intense, on-site autopsies were carried out in the river Axios, in order to identify surface holes either on the crown or the slopes of the river embankments, which would prove their presence, so that they could be selected as areas for the application of the selected techniques. Indicative photographs from the autopsies are listed below:

Photograph No 1: Embankment of Axios river

Photograph No 2: Embankment of Axios river

Photograph No 3: Embankment of Axios river canal

Photograph No 4: Embankment of Axios river canal

Photograph No 5: Myocastor on the embankment of Axios river canal

Photograph No 6: Embankment of Axios river

Photograph No 7: Slopes of the embankment of Axios river

Afterwards, field autopsies were carried out, in order to identify surface holes either on the crown or the slopes of the river embankments, which would prove their presence, so that they could be selected as areas for the application of the selected techniques.

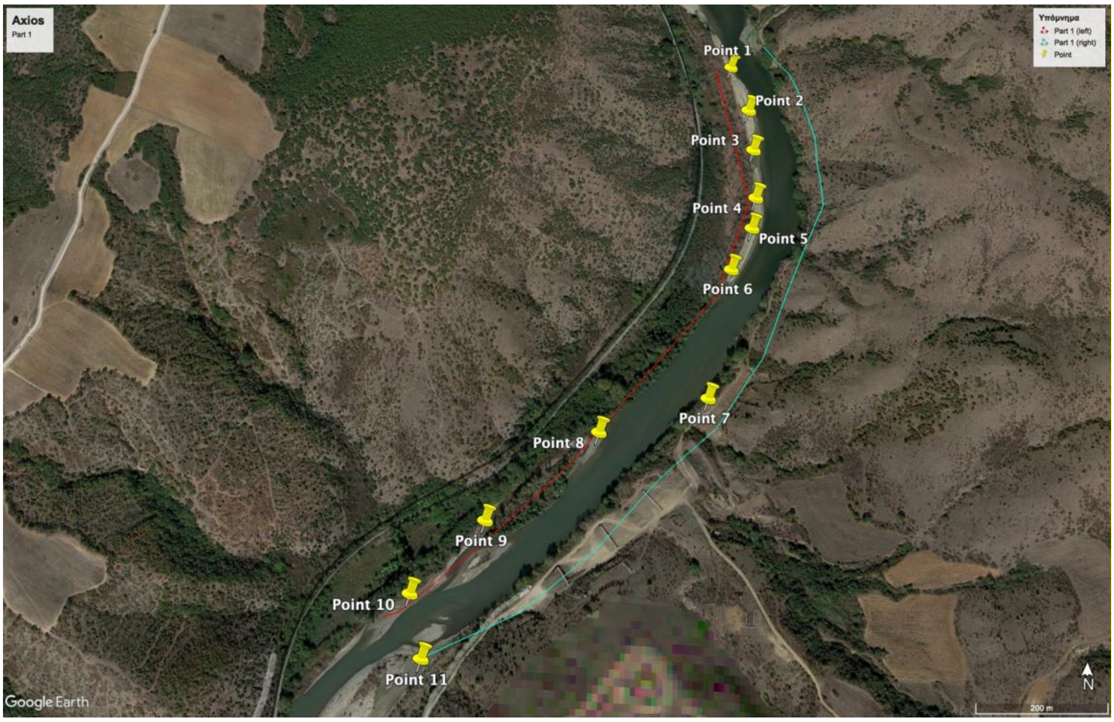
During the autopsies, it was found that the vegetation is developed and dense, consisting mainly of briers, reeds, trees and other weeds. Because of that and the fact that the use of infrared thermography is limited by the existence of intense vegetation, alternatively, for the initial detection of the existence of wild animals, it was chosen to use trail cameras, while later on infrared thermography will also be applied (mainly in the winter months when the vegetation is not so intense).

Photograph No 8: Dense vegetation on the embankment of Axios river

Trail cameras are devices that have a built-in camera and motion sensors, which as soon as they detect any movement, activate the camera to take photos and videos, and they also include date and time indications, as well as the prevailing temperature when the data is taken. Below is a photo illustration of the HC-900A trail camera to be used.

Photography No 9: Trail camera HC-900A

The study area that was initially chosen to place trail cameras is the Axios river, as for this area there were several reports about the presence of a large population of myocastors, but also a personal observation during the on-site autopsy (see photo No8). Some of the locations of the trail cameras are shown on the map below.



Map No 1: Locations of trail cameras in the Axios river.

Trail cameras were placed on trunks or thick tree branches and on wooden electricity poles in order to be as stable as possible and not be affected by strong winds. Also, the installation height was about 1m-1.20m from the ground and with a slight incline to it, so that the motion sensors could detect the movement about 20-25m away from the trail camera's installation point. An indicative illustration of the installation of trail cameras is listed in the following photo.

Photograph No 10: Installation of trail camera in No4 position.

The initial installation of the trail cameras took place on June 2023 and the data they record is collected at regular intervals until today. Indicative photos of the animals that were detected are listed below:

Photograph No 11: Detected fox by trail camera during night time, in No 5 position

Photograph No 12: Detected foxes by trail camera during night time, in No 5 position

For each location we use the following site information sheet:

<table>
<tr><th colspan="6">SITE INFORMATION SHEET</th></tr>
<tr><td>Coordinates</td><td colspan="5"></td></tr>
<tr><td>Short description of the site</td><td colspan="5"></td></tr>
<tr><td>Details of photo illustration:</td><td colspan="5"></td></tr>
<tr><td>Indicative map of the specific site.
Additional info.</td><td colspan="5"></td></tr>
<tr><td rowspan="2">Gases Concentration Rates</td><td>NH_3 (ppm)</td><td>H_2S (ppm)</td><td>CO_2 (ppm)</td><td>NO_2 (ppm)</td><td>CH_4 (ppm)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

SITE INFORMATION SHEET	
Coordinates	41° 1'57.78"B , 22°33'40.91"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *General view of the embankment*	
Indicative map of the specific site. Additional info.	

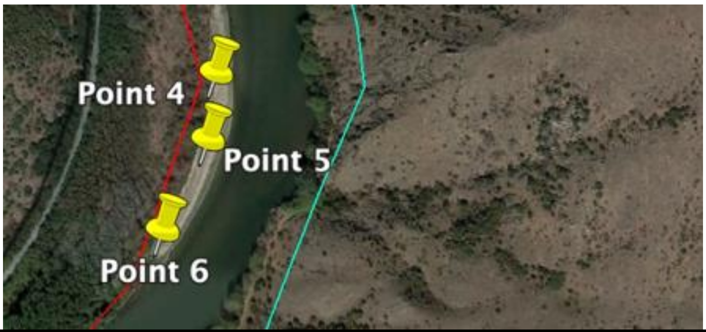
Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	48.6	11.5	5872	0.64	6860

SITE INFORMATION SHEET	
Coordinates	41° 1'55.02"B, 22°33'42.25"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *Hole made by mammalian on the embankment*	
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	48.8	12.7	5664	0.72	6793

SITE INFORMATION SHEET	
Coordinates	41° 1'52.57"B, 22°33'42.59"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *Hole made by mammalian on the embankment, deeper than the one of point 2*	
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	49.2	11.7	5864	0.65	6891

SITE INFORMATION SHEET	
Coordinates	41° 1'49.63"B, 22°33'42.72"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *Hole made by mammalian on the embankment. (Vertical opening)*	
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	42	11.2	5320	0.67	6428

SITE INFORMATION SHEET	
Coordinates	41° 1'47.79"B, 22°33'42.41"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration	No photo available
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	38	10.3	4790	0.57	6130

SITE INFORMATION SHEET	
Coordinates	41° 1'45.32"B, 22°33'40.82"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration	No photo available
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	35,6	8.36	3957	0.49	4653

SITE INFORMATION SHEET

Coordinates	41° 1'37.89"B , 22°33'39.09"A
Short description of the site	Right bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *General view of the Right trench of central River flow*	
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	32	9.76	4230	0.47	5690

SITE INFORMATION SHEET					
Coordinates	41° 1'35.85"B. , 22°33'31.05"A				
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)				
Details of photo illustration: *General view of theleft trench of central River flow*					
Indicative map of the specific site. Additional info.					
Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	39.7	10.6	4650	0.58	4983

SITE INFORMATION SHEET	
Coordinates	41° 1'30.86"B, 22°33'22.92"A
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration	No photo available
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	32.4	9.56	3591	0.37	1597

SITE INFORMATION SHEET					
Coordinates	41° 1'26.87"B, 22°33'17.74"A				
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)				
Details of photo illustration	No photo available				
Indicative map of the specific site. Additional info.					
Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	49.7	11.56	5689	0.66	6791

SITE INFORMATION SHEET	
Coordinates	41° 1'23.49"B, 22°33'18.75"A
Short description of the site	Right bank of Axios River upwards of Polikastro (Central bed)
Details of photo illustration: *Discontinuity of the embankment due to hole's existence*	
Indicative map of the specific site. Additional info.	

Gases Concentration Rates	NH_3 (ppm)	H_2S (ppm)	CO_2 (ppm)	NO_2 (ppm)	CH_4 (ppm)
	39.7	10.6	4650	0.58	4983

In the areas where animals are detected with the help of trail cameras, we made new autopsy and found impressive holes like the ones as follows:

Photograph No 13: Hole near the embankment of Axios river

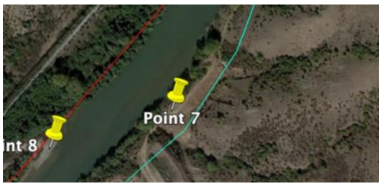
Photograph No 14: Hole near the embankment of Axios river

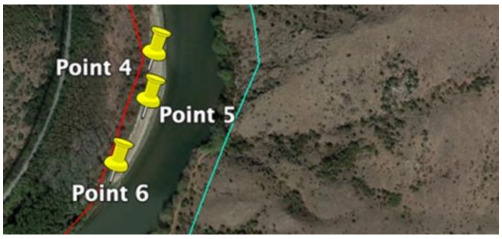
Photograph No 15: Hole on the embankment of Axios river canal

Moreover, we confirmed the Mammalian existence, by inserting in the same holes gas detectors where the values of gas, like the one of CH4, present remarkable increasement.

In the picture below you can see the relevant equipment.

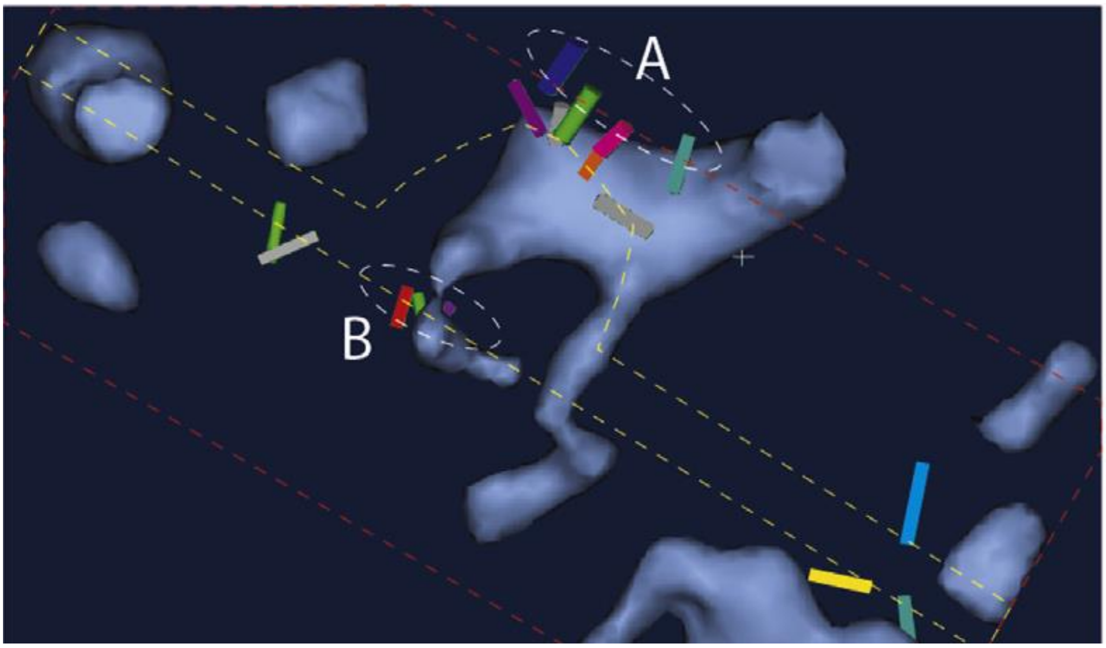
In Axios the animals that detected by the trail cameras were foxes and myokastors. Moreover, it was found that the detectors of trail cameras were activated by the movement of the weeds during the windy periods and so all the data of these periods refer to recordings of their movement. Therefore, special attention should be paid so that the installation of trail cameras in the other study areas will be carried out in places where the vegetation is not developed.

SITE INFORMATION SHEET					
Coordinates	41° 1'37.89"B , 22°33'39.09"A				
Short description of the site	Right bank of Axios River upwards of Polikastro (Central bed)				
Details of photo illustration: *General view of the Right trench of central River flow*					
Indicative map of the specific site.					
Gases Concentration Rates	NH3 (ppm)	H2S (ppm)	CO2 (ppm)	NO2 (ppm)	CH4 (ppm)
	44	10.8	5670	0.6	5700

SITE INFORMATION SHEET					
Coordinates	40.968066, 22.574690				
Short description of the site	Right bank of Axios River upwards of Polikastro (Central bed)				
Details of photo illustration: *Foxes on the embankment (night view)*					
Indicative map of the specific site.					
Gases Concentration Rates	NH3 (ppm)	H2S (ppm)	CO2 (ppm)	NO2 (ppm)	CH4 (ppm)
	48.3	11.7	5642	0.65	6751

SITE INFORMATION SHEET					
Coordinates	41° 1'57.78"B , 22°33'40.91"A				
Short description of the site	Left bank of Axios River upwards of Polikastro (Central bed)				
Details of photo illustration: Myocastor on the upper side of the embankment (photo taken by trail camera)					
Indicative map of the specific site.					
Gases Concentration Rates	NH3 (ppm)	H2S (ppm)	CO2 (ppm)	NO2 (ppm)	CH4 (ppm)
	47,1	11,0	5570	0,63	5913

(a)


A
B


A

Using ground penetrating radar in levee assessment to detect small scale animal burrows

3 Results

As a result, we can say that the method of trail cameras presents remarkable results, as far as, it concerns the detection of mammalians existence, inside the bodies of the embankment. This method is simple and cheap and it is not affected by the vegetation density, something that affects all other methods which referred before and which are complicated and expensive.

Nevertheless, the recent presence of Mammalians inside the holes must be confirmed by the use of Gas detectors, who detect gases produced by the vital functions of the mammalians, something that was illustrated in the information sheet which filled in, in the field, with the appearance of increased values.

Both actions, trail cameras photos and values of vital functions gases are the proofs for mammalians presence in the river’s embankments.

The general conclusion is that with the help of trail cameras in the one hand and the confirmation of gas detectors in the other, we can detect primarily the existence of mammalians and more specifically the areas of their entrance and exit in the above, while with the help of gas detectors, we confirm as a second step, their recent presence inside the holes.

Both are quite useful in order to detect the areas where there is a need of technical intervention, aiming to the repairment of the holes and discontinuities, something that has as a result to the safe and steady operation of embankments during the crucial time of flood action and as a consequence their optimum anti-flood protection.