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Review and rebuttal of the paper

Assessing the extent and connectivity of animal burrows using smoke: a practical tool for levee inspections

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Handling editor: Miguel Esteban

REVISION ROUND 1: Comments and response

Dear editor and reviewers,

We sincerely appreciate your constructive suggestions and comments on our manuscript.
We have adapted the manuscript according to your remarks. In the following, you will find our replies (in blue) to your comments (in black) and the improved or corrected text passages (in blue, between ‘’). The page and line numbers in black refer to the original document, page and number lines in blue refer to the revised document.

We are looking forward to hearing from you.

Kind regards,
the authors

Reviewer 1
This is a well written manuscript. The objective of this study is to develop a practical and low cost solution for the quick detection of interconnected burrow openings. The methodology described in this research is unique and it can be useful as a low cost real time levee inspection method for quick detection and risk assessment of structural failure. However as a newly developed method it has it's own limitations which are also discussed in this paper and hopefully will be addressed in the future research work. Thank you for reviewing the manuscript.

Minor correction is required in the Introduction part for a reference Owings and Borchert, 1975. (page2, line 25) Thank you for noticing, we have adjusted this. (page 2, line 25)

Reviewer 2
The short communication entitled "Assessing the extent and connectivity of animal burrows using smoke: a practical tool for levee inspections" presents a handy and easy to implement application for the assessment of the subsurface connectivity of animal burrows. The topic is of interest to the field of the JCRFR and includes novel aspects which could be useful for the rapid assessment of levee structural conditions in combination with motre sohisticated solutions.
The short communication is concise and properly organized. The abstract, objectives and literature review are well written. The (rather simple) methodology is properly explained, but there are a few details that could be improved. The results should be better explained, particularly regarding those in Table 1. The discussion could be improved and perhaps avoid the "manual-type" of text style used in some passages. The author(s) should highlight that the assessment is superficial and has limitations when dealing with the 3D structure of the burrow network; some of the detected limitations of the method are commented in the attached pdf file. Additionally, the authors could mention ways in which the method could be improved, some of which are also commented in the pdf. Finally, some speculative comments in the discussion should be either based on evidence or disregarded from the short cmmunication. Several specific comments are included in the pdf file.
Thank you for reviewing the manuscript. See responses to specific comments below for detailed answers.
To improve the explanation of the method, a scheme has been added (Fig 1, page 3). We have slightly altered the method and result section (including the caption of table 1, page 8) to clarify where certain results came from.

We believe the 'manual-type' text style was mostly applicable to the passage 'Operational considerations and safety measures', therefore the first part of the paragraph was re-written: 'The smoke bombs utilized in this investigation are commercially available for outdoor applications. It is imperative to carefully review and adhere to the safety guidelines outlined by the manufacturer of the smoke device used. To minimize exposure to the smoke, the technique should be exclusively tested and employed in an open-air setting. Individuals handling the smoke device and/or leaf blower are advised to wear appropriate safety gear, including heat-resistant gloves, protective eyewear and face mask.' (page 9, line 14-18)
To highlight the limitations of the technique, the sentence of the method section was adjusted (page 4, line 19; page 5, line 14-16) and of the discussion (page 10, line 50-51).
We have added more ways to improve the method, such as increasing the flow rate and density of the smoke (enhance visibility) and the use of a drone (page 10, line 5-8, 13-16).
The speculative sentences have been modified or deleted from the discussion (page 10, line 37-47).

Page 2, line 28-30: Therefore, this study aimed to develop a practical and low-cost approach utilizing smoke that allows the quick detection of interconnected burrow openings on the surface that signify the presence of interconnected cavities on the subsurface.
This sentence was adapted to: 'Therefore, this study aimed to develop a practical and low-cost approach utilizing smoke for the quick detection of interconnected burrow openings on the surface, signifying the presence of interconnected cavities in the subsurface.' (page 2, line 28-30)

Page 3, line 11: comment PWG1: Could you please specify what this acronym stands for?
HK are the initials of the first author.

Page 3, line 16-17: Delete 'that is located'
We have deleted this as suggested. (page 4, line 3-4)

Page 4, line 6: comment PWG2: I would speculate there are two types of burrow density: volume and surface. I suggest using local surface burrow density to be more precise.
We have adjusted this as suggested. (page 4, line 19)

Page 4, line 11-12: comment PWG3: Could you please specify why production is measured in m^2?
We agree that this unit is counterintuitive, however, this is the only specification provided by the manufacturer of the smoke generating devices. The specifications can be found on the webpage (https://www.fakkelshop.be/products/standaard-rooksignaal-mr-smoke-2?_pos=1&_sid=00e6f9860&_ss=r) under 'Productspecificaties'.
Revision round 2: Any chance to comment on this in the manuscript? The reader will be doubtful (as me) if no further explanation is provided.
The production company was contacted but did not provide further clarification. It was decided to remove this specification from the text as it does not provide useful information, it can only be used to compare smoke devices from the same manufacturer.

Page 4, line 16: comment PWG4: I wonder if the "multiple people" were enough to capture the emergence in several holes. I also wonder if the method could be improved by using a static drone on top of the site, in combination with video postprocessing, to better determine the emergence of smoke?. Obviously, this is not the scope of the paper and the drone method could also bring new challenges to deal with. This could be mentioned in future research or discussion.
Page 4, line 18-19: comment PWG5: Following the previous comment, the distance could be better measured with a rectified orthophoto taken from a drone, or a standard topographic survey. This could also be discussed later.

That is indeed an interesting idea. We do believe that a static drone would not work, because when the smoke emerges from multiple nearby burrows, they can mask each other due to the diffusivity of the smoke. As a result it would not be possible to identify the point location of the burrow openings. In cases where a large area needs to be covered, a drone that takes pictures from different angles could be an added value. However, this would be at the expense of a long post-processing time, which cancels out one of the main advantages of the technique (i.e. immediate results and no specialised equipment needed). Also, in the current set-up, smoke bombs were used that emitted smoke for about 1 minute, it is questionable that the drone would have enough time to capture the area from different angles within that time frame. Therefore we argue that in the current set-up the drone would not have an added value. We do agree that in the future, it would be very interesting to explore other smoke sources in combination with a drone, potentially equipped with an infrared sensor.
We have added the following text to the discussion in line 13-16 on page 10: 'In the future, the use of a drone (potentially equipped with an infrared sensor) to detect smoke emerging from burrows, could be explored to aid burrow detection during the smoke test. The drone could also aid in identifying burrow locations over a large area more efficiently, prior to the smoke test (i.e., replacing the tape measure mapping approach).'

Page 4, line 21: comment PWG6: Perhaps use "site"?
Adjusted. (page 4, line 35)

Page 5, line 4: comment PWG7: This may be a peregrine question, but what are the consequences animals within the borrows could have to the exposure to smoke?. I would guess concentrations are low and exposure short to cause effect, but a more informed comments from the reviewers would be welcome.
This is definitely a valid question. The smoke bombs used in this experiment had a burning time of 60 s, so exposure was limited. The pressure of the leaf blower also ensures that the smoke is blown out of the burrow network, therefore exposure after the test will be limited as well. That said, if there are animals present in the burrows, the smoke can cause stress and irritation of the respiratory tract, eyes, mouth, nose and throat (disclosed in the safety sheet of the devices). Furthermore, the smoke can deposit a residue (especially on damp surfaces), which can cause health problems when ingested. We did not investigate this, therefore we cannot define which exposure would have adverse effects.

Page 5, line 11: comment PWG8: By "architecture", though a generic term, I would expect a spatial (3D) characterization of the structure of the burrows (which could eventually be characterized with geophysical tools). I would lower the expectations of the reader and perhaps be more specific.
Sentences were modified to: 'The smoke test was used to gain more knowledge on the superficial spatial configuration and dimensions of different burrow types encountered on levees. Additionally, the study aimed to evaluate its utility as a tool for levee inspectors to identify burrow openings, the extent of the burrow network and the risk it poses.' (page 5, line 14-16)

Page 5, line 13-14: comment PWG9: Sorry; could you explain what this mean?
Interreg is a series of European Union (EU) programs designed to promote cross-border, transnational, and interregional cooperation across Europe. Interreg programs aim to foster collaboration and address common challenges faced by regions in different EU member states. The programs support projects that encourage the exchange of experiences and best practices, contributing to integrated development and mutual understanding among participating regions.
We have deleted the sentence, as it will be mentioned in the acknowledgements (will be added after review). (page 5, line 17)

Page 6, line 25-26: comment PWG10: Suggestion: If the authors aim to make this handy method available for everyone, I would suggest using diagrams to schematize the temporal sequence and spatial configuration of tests repetitions. Just a suggestion, though.
Thank you for this suggestion, this could indeed be beneficial. We have added a scheme (line 1-2, page 3) to clarify the procedure.
Additionally, we adjusted all the figure numbers:

- Page 2: L37-38: added '(Fig. 1)', L41
- Page 3: L5
- Page 4: L4, L8, L15, L18, L20, L21, L30, L33
- Page 5: L2, L5, L20, L22
- Page 6: L7, L14, L17, L20, L22 added '(Fig. 1)', L28, L30, L32, L33, L35
- Page 7: L2, L6, L9
- Page 8: L19
- Page 9: L2, L8, L9

Page 8, table 1: comment PWG11: Suggest surface burrow density, no?
We have adjusted this as suggested. (page 8, table 1)

Page 8, table 1: comment PWG12: How to interpret this result?. Is there a statistical analysis?. What kind of uncertainty (error, accuracy, precision) is this number representing?. Same comment for the following results in this column.
The values represent the average ± standard deviation, this is indicated in line 14 of the same page. In the first case study seven different burrow networks of the Chinese mitten crab were tested, this means that we performed the test on seven different locations within the creek. From this we derived for example that per inlet hole, on average 10 burrow openings are connected beneath the surface, with a standard deviation of 6.
We have adjusted the caption of the table (page 8, line 14-15) to state this more specifically: 'In case-study 1, multiple burrow networks were tested, therefore the average values are shown with standard deviation when applicable.'

Page 8, table 1: comment PWG13: How is this value obtained from the tests?
These values are derived from measurements with inspection probes for case study 2 (prior to the smoke test) and from literature for case study 1. It is an important parameter for the characterisation of the burrow network. Not all the data in the table are obtained with the smoke test itself, as indicated in the caption of the table.
The method section was adjusted to clarify this: 'with inspection probes (Fig. 7a)' was deleted in line 11 page 6, and 'Depth was measured using inspection probes (Fig. 7a). The map helped the team identify clusters of burrows of small rodents and moles that could be leading to subsurface dens.' was added in lines 14-15 page 6.
On page 8, line 8-9 was modified to: 'Although measurements with inspection probes indicated that burrow depth was in general less deep than the clay layer of the levee at the respective locations, evidence was found in later research that some burrows at location 2 of case study 2 reached the sand core (Tsimopoulou & Koelewijn, 2022).'
The caption of the table was modified as well (page 8, line 13-15): 'Table 1: Overview of the characteristics of the different burrow networks that were studied. Data are derived from the smoke test and the inspections prior to the test. In case-study 1, multiple burrow networks were tested, therefore the average values are shown with standard deviation when applicable.'

Page 9, figure 9: comment PWG14: I suggest using some sort of scale to facilitate interpretation.
We have adjusted the graph as suggested. (page 9, figure 10, line 1)

Page 9, line 10-11: comment PWG15: Just a curiosity. How to guarantee safety of the inspectors when exposed to smoke?. Or it would just be a nuisance rather than a health risk?. In oceanographic surveys, for example, some substances (e.g. rhodamine) are banned or allowed to be used in very small concentrations. There are very strict protocols on this regards; however, I have no clue if the same apply to gaseous materials.

The safety sheet indicates potential health risks associated with the smoke bombs. The document highlights harmful effects if ingested, inhaled or in contact with skin or eyes. As with all substances, this is concentration-dependent. So to answer the question: we argue that in open air and with the use of protective gear for people close to the smoke source, the health risk is limited. The smoke bombs are sold in retail for outdoor use, so if safety instructions of the manufacturer of the device are followed, they should be safe to use. As indicated in the discussion, we do encourage the exploration of other smoke sources. However, it is probable that all potential smoke sources can carry health risks when ingested or heavily inhaled.

We have modified the sentences related to this topic in the discussion (page 9, line 14-18): 'The smoke bombs utilized in this investigation are commercially available for outdoor applications. It is imperative to carefully review and adhere to the safety guidelines outlined by the manufacturer of the smoke device used. To minimize exposure to the smoke, the technique should be exclusively tested and employed in an open-air setting. Individuals handling the smoke device and/or leaf blower are advised to wear appropriate safety gear, including heat-resistant gloves, protective eyewear and face mask.'

Page 9, line 20-22: comment PWG16: This is an interesting issue. Future experiments could test with more dense smoke by, for example, cooling it. In such a way, both the upper and lower parts of the injection point could be characterized.

We do not fully understand the comment, we think it is suggested that cold smoke sinks while hot smoke rises and that this could be an issue. As is written in line 23-25 on page 9, the lower part of the injection point could be characterized, as smoke was observed from burrow openings below the inlet hole as well. This means that the smoke travelled both up and down, this is because the leaf blower dominates the transport.

Revision round 2: May recommendation is beyond the scope of the actual experiments, son let's leave it aside.

Page 9, line 22: comment PWG17: I don't recall reading about the different colours used. I would suggest expanding on this issue.

We did not provide all the details on this, thank you for drawing our attention to this. For the first case study, the colours used can be found on line 25 on page 4. For the second case study the following information was added on lines 26 and 29 on page 6: '(orange, red)' and '(red, blue, purple)'.

Furthermore, text was added and modified in lines 25-28 on page 9: 'The brightly coloured smoke significantly enhances the detection of smoke emerging from burrow openings. In this study, five distinct colours were tested: red, orange, pink, blue and purple. During the tests on unvegetated slopes, all different colours of smoke were clearly visible. On slopes covered with dry grass, blue and purple smoke were generally well visible, while orange and red smoke were less favourable.'

Page 9, line 23-24: comment PWG18: Meteorological conditions were briefly commented, but no systematic analysis is provided beyond that. This rather absolute sentence is restricted to two cases under scrutiny and cannot be extrapolated. I'd suggest modifying it.

These lines were modified as indicated in the response to the previous comment.

Page 9, line 25-26: comment PWG19: This sentence sounds speculative. I'd suggest eliminating it.

We have deleted it as suggested. (page 10, line 4)

Page 9, line 26: comment PWG20: I would speculate there are other ways to improve the tests: increasing the concentration, or increasing the flux, among others. Is that feasible?. Is it worth commenting it on the paper?
Thank you for your interesting suggestion. We have deleted the sentence 'In such cases use of a windscreen or repetition of the test a second time is advised.' and added the following text to the discussion to address the comment: 'Increasing the concentration and flux of the smoke represents a potential avenue to maximise the visibility of smoke in such conditions. To achieve this, the use of a smoke source with greater smoke output and a leaf blower with a higher air flow rate or different specialised equipment can be explored.' (page 10, line 5-8)
Furthermore we modified line 11-14 on page 11 (conclusion): 'It is recommended to conduct additional research on factors influencing test outcomes, including burrow size, soil properties, and soil water content. Moreover, further investigation into elements that maximize smoke visibility, such as smoke concentration and flux, is also advisable.'

Page 9, line 26-28/Page 10, line 1-2: comment PWG21: These text sound a bit speculative ("it is possible", "could"). Any chance to avoid tis type of wording?
These sentences were modified as follows: 'A tunnel or burrow blocked by water can obstruct the smoke test. In the tidal area (case study 1) investigated in this research, the pressure exerted by the leaf blower was observed to overcome this limitation, as water was seen bubbling up from burrow openings during the test.' (page 10, 9-12)

Page 10, line 4: delete comma
Deleted (page 10, line 17)

Page 10, line 5: comment PWG22: What do you mean by this term?
We want to indicate that the smoke bombs are safe for people to use. This includes both safety in the practical use of the product (e.g. transportation, ignition) and health risk (e.g. from inhaling smoke). Also see response to earlier comment (comment PWG15).

Page 10, line 25: delete s of allows
This sentence is modified, see following comments.

Page 10, line 26, comment PWG23: I'd say there is no formal analysis of precision nor accuracy, as no benchmark is used to compare these results.
Page 10, line 27-28: comment PWG24: What do authors mean with this?
Page 10, line 28-29: comment PWG25: Same. Please avoid these types of comments which are not based on evidence.
We removed 'precision' from the sentence and modified the text to underscore the advantage of the smoke test in terms of speed (no post-processing needed, immediate results). Hopefully this clarifies and addresses the three former questions/remarks.
The text (page 10, line 37-47) was adapted to: 'Its rapid deployment and immediate results facilitate inspectors in quickly identifying burrow openings in a non-destructive way, thereby revealing potential weak points in the levee. The speed of this approach addresses a critical gap in current inspection methods, providing inspectors with a valuable tool and a distinct advantage in scenarios where time is limited. The method's primary focus is on protecting human life during levee failures, particularly in emergency situations, despite acknowledging its potential impact on animals.'

Page 11, line 5: comment PWG26: Please provide this information.
Page 11, line 7-10: comment PWG27: Please provide this information.
As requested by the editor, this information will be included after the second review round to enable double-blind review.

REVISION ROUND 2: Comments and response

Reviewer 1

The short communication entitled "Assessing the extent and connectivity of animal burrows using smoke: a practical tool for levee inspections" has improved significantly after the first round of review. The methodology used in this particular research is very original and it has practical importance for levee detection. However Figure. 1 which shows the schematic diagram of the methodology can be improved with fewer text and a better visual impact. We have adjusted the figure. Quantitative evaluation of the result i.e., the success rate of this method in levee detection should also be added in the discussion part. The method aims to deliver an approximation of the spatial extent and does not have to be meticulously accurate. The approximation of the spatial extent is very useful for levee inspectors as it hints at how vulnerable a certain levee section might be. In case of an emergency setting this information is very valuable in making decisions about the next steps. If there is no emergency setting, the information can be used as an indication that a specific location needs to be measured more thoroughly, with e.g. ground penetrating radar or electric resistivity tomography. Therefore, no quantitative measurements were made to evaluate the success rate of the method and mentioning it seems redundant.

A minor correction for all the figures with (A), (B) etc should be replaces by (a), (b) etc to match with the text. This was corrected.

Reviewer 2

The authors have clarified several concerns and have modified the text whenever requested. I am fully satisfied on how they addressed the review process. I enclose a word file with minor recommendations which can be quickly addressed with no further review from my side. (See added comments in previous section)

Our decision is to: Accept with minor revisions