International Association of Chinese Infrastructure Professionals

Climate Adaptive Management of Solid Waste Disposal Facilities using Drone-based Sensing Technology for Decision Making

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Motivation


(a) (b)

Fig. 1: (a) Properly managed landfill and (b) an open dump site

Municipal solid waste (MSW) landfills are well-engineered and managed facilities for the disposal of household waste that are designed to protect the environment from contaminants

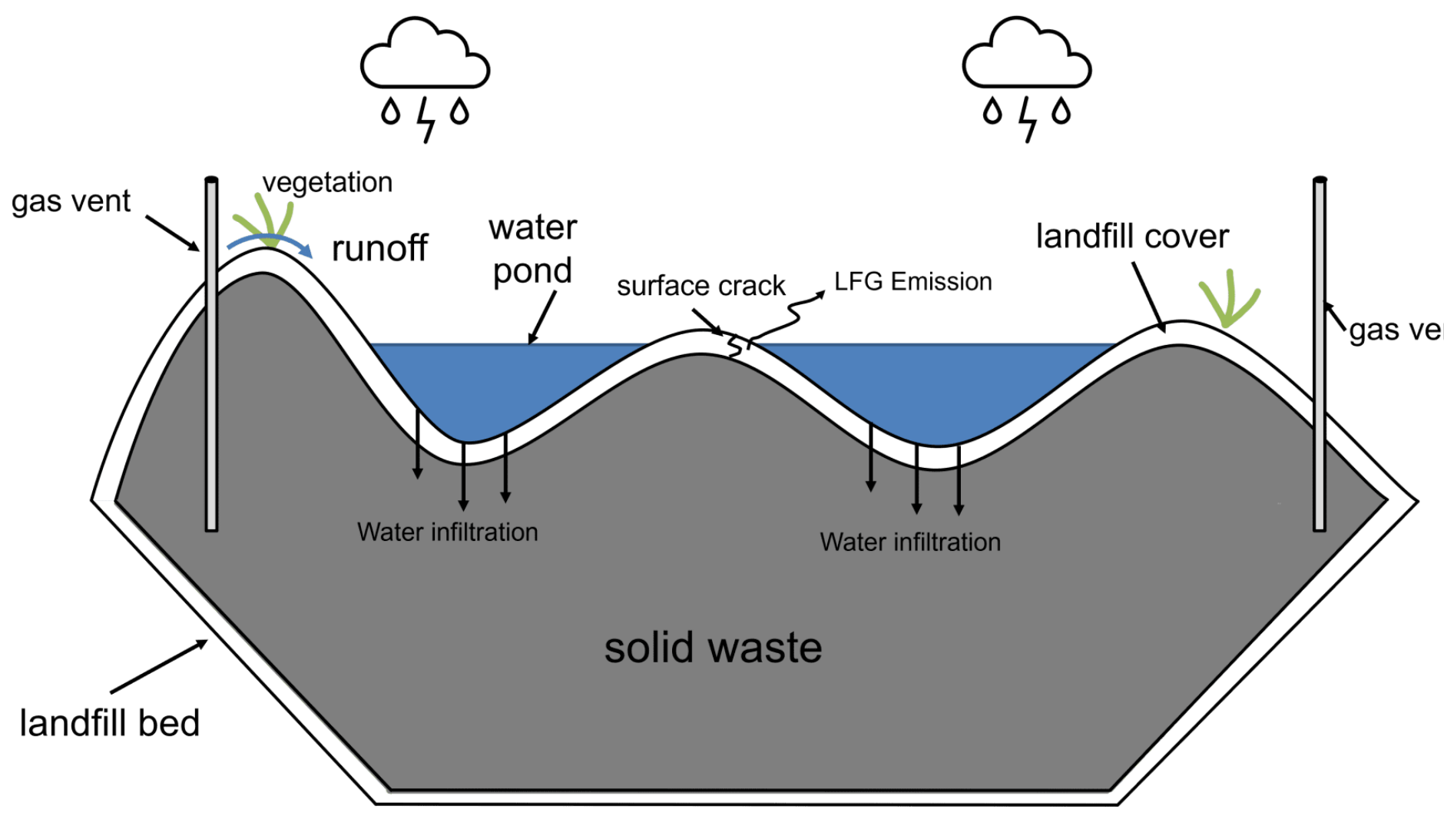


Fig. 2: Schematic view of a landfill

MSW landfills usually undergoes topological depression due to stagnant water.

Water ponding leads to surface cracks and water infiltration resulting in landfill gas (LFG) emission.

This study proposes a drone-based (UAV-based) sensing approach and data collection/analysis method to monitor landfill emissions and cover conditions with cost-effective sensing methods and shortens the survey durations.

Equipment & Experiment

This study proposed an idea for UAV-based MSW monitoring to automate landfill monitoring and maintenance processes. A Ponding Index (PI) was proposed by diffusing multiple data together that was collected from UAV-based multi-sensing approach.

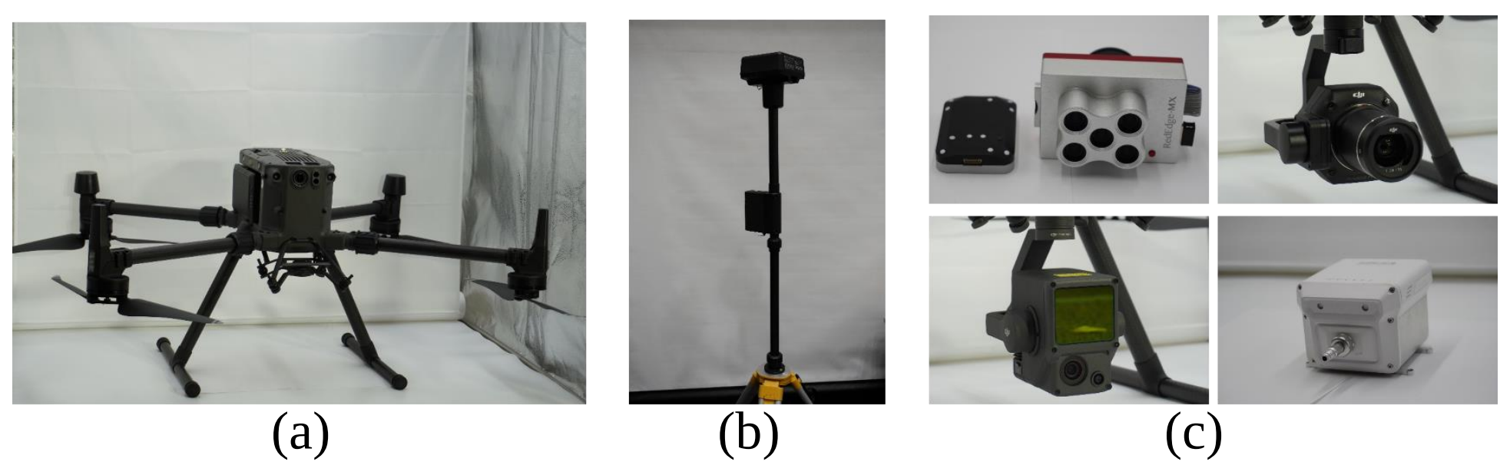

(a) (b) (c)

Fig. 3: (a) M300 RTK drone, (b)RTK base station, and (c) UAV-based sensing payloads

Southeast landfill, Hillsborough county in Tampa, FL was selected as study area as shown in Fig. 4 with highlighted Hurricane path in red [Fig. 4(a)]. Data was collected after performing multiple UAV-based context aware flights for air quality sensing, multispectral and LiDAR scanning as shown in Fig 5.

Methodology

After integrating data from different UAV-based sensing payloads, ***"Ponding Index (PI)"*** is proposed in this study to indicate the areas of either topological depression or the presence of excessive moisture/surface water on top of the landfill. Derivation of PI is based on previously established research findings.

– **Low intensity** (LRI) value = **High water** content in ground [(Hooshyar et al., 2015) and (Höfle et al., 2009)]

– **High flow accumulation** (NFA) value = **High chances of water** presences/topological depression (O'Callaghan & Mark, 1984)

– **High normalized difference water index (NDWI)** value = **High water** content in vegetation (Work & Gilmer, 1976)

Therefore,

$$PI = \alpha \cdot \frac{1}{LRI} + \beta \cdot NFA + \gamma \cdot NDWI$$

where "α", "β" and "γ" are the weights. Higher PI value means high chances of water being stagnated or can possibly be stagnated at a specific location.

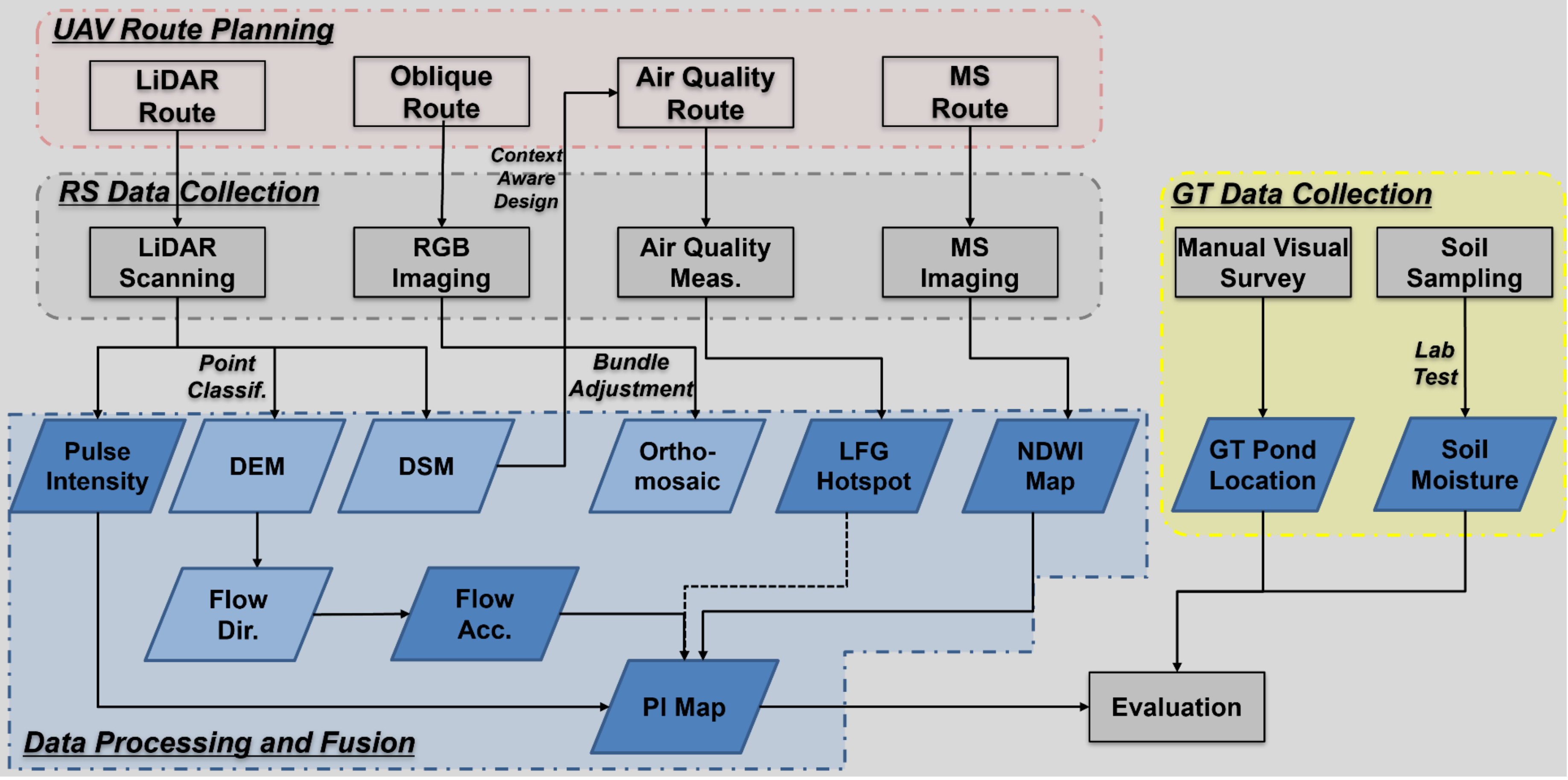
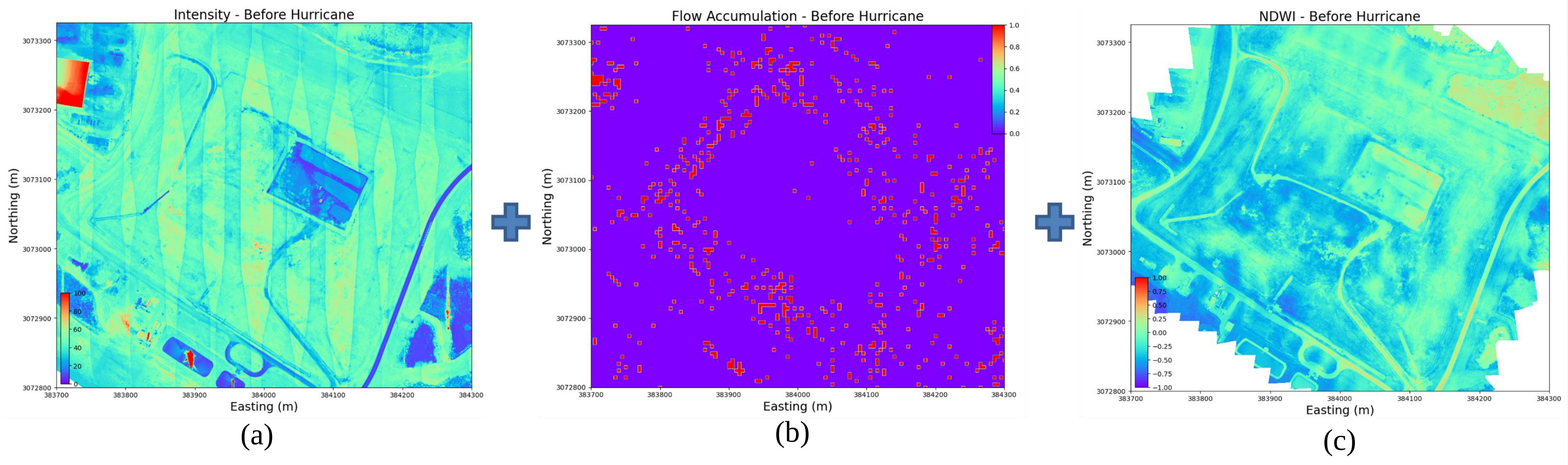

UAV Route Planning
LiDAR Route
Oblique Route
Air Quality Route
MS Route
Context Aware Design
RS Data Collection
LiDAR Scanning
RGB Imaging
Air Quality Meas.
MS Imaging
GT Data Collection
Manual Visual Survey
Soil Sampling
Point Classif.
Bundle Adjustment
Lab Test
Pulse Intensity
DEM
DSM
Ortho-mosaic
LFG Hotspot
NDWI Map
GT Pond Location
Soil Moisture
Flow Dir.
Flow Acc.
PI Map
Evaluation
Data Processing and Fusion

Fig. 6: Workflow for calculation of PI by data fusion

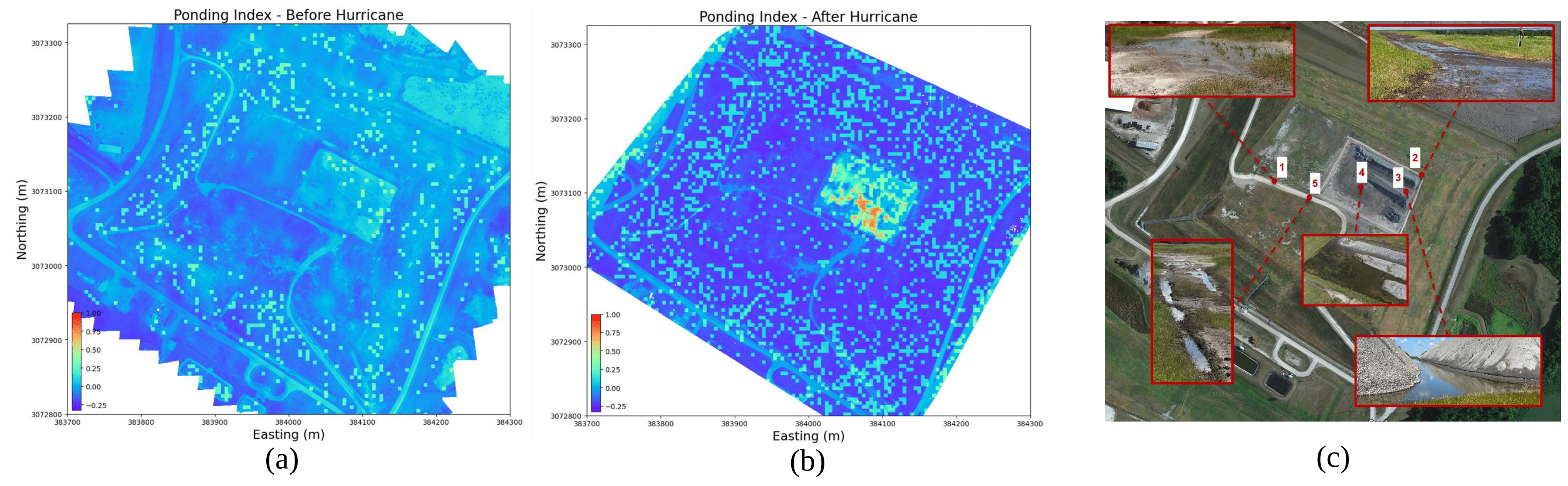
Result and Discussion



(a) (b) (c)

Fig. 7: (a) Intensity map, (b) Flow Accumulation map, and (c) Water index map (NDWI)

Intensity maps and flow accumulation maps were generated from LiDAR data and water index (NDWI) map was generated from multispectral data. These maps were then fused together to get ponding index (PI) in Fig. 8. Warmer color in Fig. 8 shows areas (5m × 5m) with higher PI, indicating a higher probability of topological depression or potential water ponding/wet regions.



(a) (b) (c)

Fig. 8: (a) PI maps before, (b) after Hurricane Ian, and (c) Ground truth observations after Hurricane

Ponding regions in after Hurricane case were in alignment with ground truth on multiple locations as indicated in Fig. 8(c).

Equipment & Experiment (Cont.)

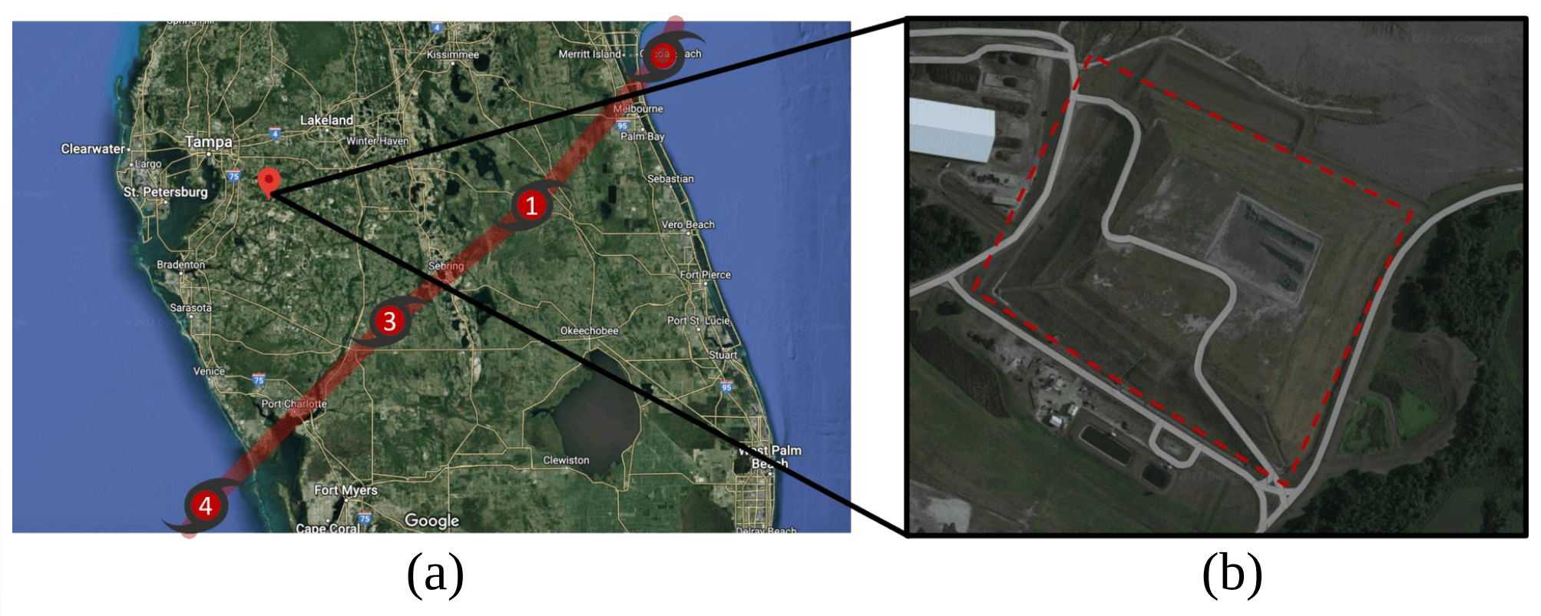

(a) (b)

Fig. 4: (a) Landfill location (b) region of study of the landfill

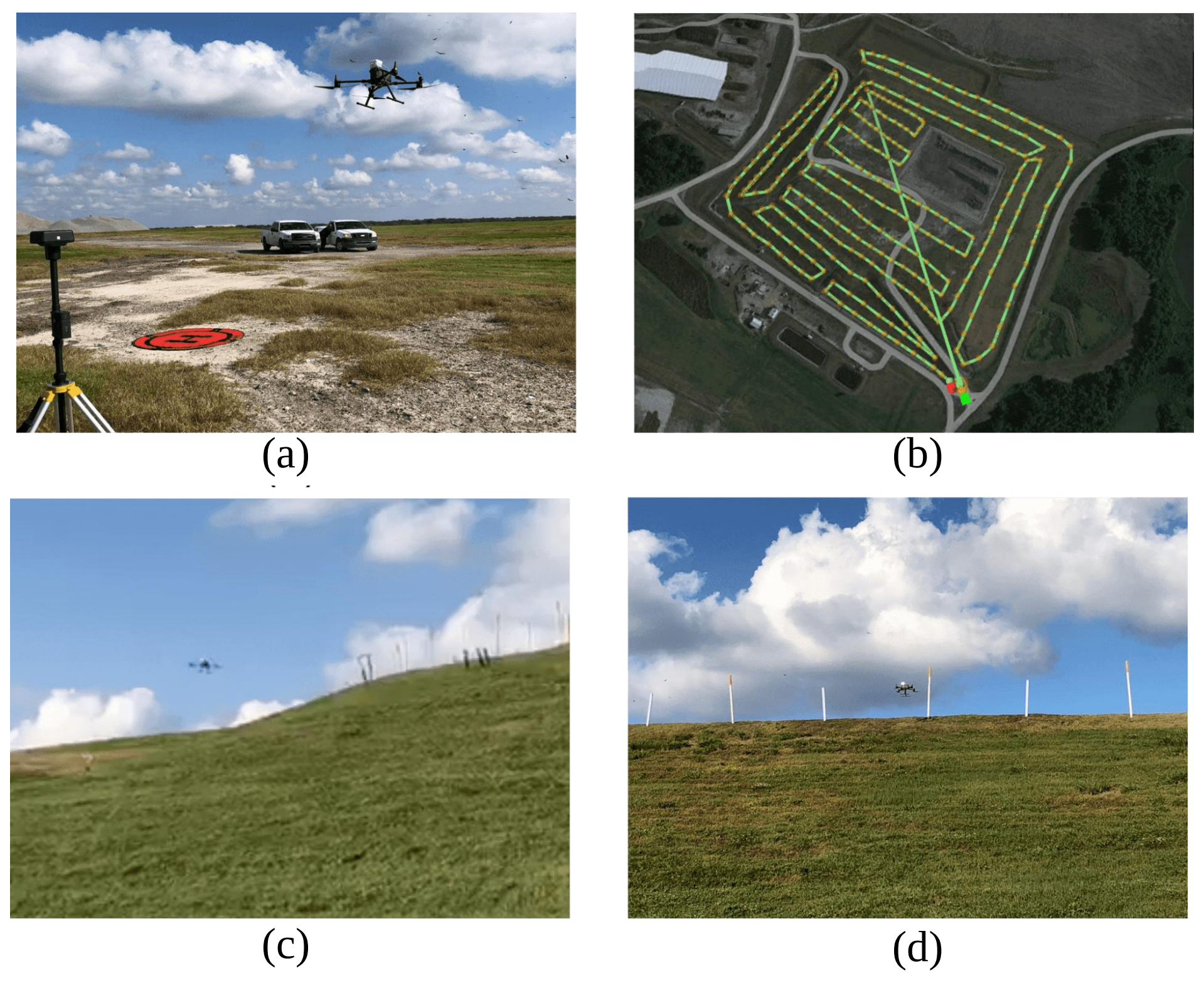

(a) (b) (c) (d)

Fig. 5: (a) UAV route planned for sensing (b) above the top surface, and (c-d) above the slope of landfill cover

Conclusion

To satisfy the practical needs in MSW landfill management, such as effective surveying and landfill cover issue detection (e.g., water ponding), this study proposes a UAV-based sensing approach and data/image processing and analysis strategy for robust water ponding detection on the surfaces of landfills with cost-effective sensing methods and shortened survey durations.

References

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Work et al., Utilization of satellite data for inventorying prairie ponds and lakes.

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