International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Exploring the Landscape of UAV Image Processing Tools: Insights into Capabilities and Industry Applications

Semen Levin[1], Egor Sokolov[2]

[1]Professor, Department of Automated Control Systems, Tomsk State University of Control Systems and Radioelectronics
[2]Department of Automated Control Systems, Tomsk State University of Control Systems and Radioelectronics

Abstract
The rapid advancement of UAV technology has significantly enhanced forest management and environmental monitoring capabilities, providing a dynamic platform for detailed data collection and analysis. This study aims to evaluate various UAV image analysis software tools, focusing on their performance across critical criteria such as accuracy, functionality, processing speed, and user interface. Using a structured methodology that includes quantitative and qualitative assessments, each software was scored on a scale of 0 to 10 and weighted according to its practical significance. The results revealed distinct strengths and capabilities: Pix4Dmapper excelled in functionality and feature richness, DroneDeploy in user accessibility and processing speed, Agisoft Metashape in accuracy, and Correlator3D in rapid data processing. Tools like Trimble UASMaster and Global Mapper demonstrated balanced capabilities, making them suitable for diverse applications. The findings underscore the importance of selecting software based on specific project needs, highlighting the need for continuous innovation and adaptation in UAV image analysis technology to meet evolving requirements. This review provides valuable insights for organizations and individuals aiming to optimize their geospatial data collection and analysis operations.

Keywords: UAV Image Analysis, Forest Management, Environmental Monitoring, Geospatial Data, Photogrammetry, Image Processing Software, Pix4Dmapper, DroneDeploy, Agisoft Metashape, Correlator3D, Trimble UASMaster, Global Mapper, ENVI OneButton, Propeller Aero, Maps Made Easy, Automated Image Analysis, Remote Sensing, GIS Integration, Data Accuracy

1. Introduction

Integrating Unmanned Aerial Vehicles (UAVs), commonly called drones, into forest management and monitoring has revolutionised how these ecosystems are studied and preserved. UAVs offer a dynamic platform for rapid, repeatable, and highly detailed data collection, proving invaluable in environmental conservation and management, particularly in expansive and inaccessible forested areas [1].

One of the primary applications of UAV technology in forestry is monitoring tree populations, health assessments, and detecting changes due to environmental factors or human activity [2]. These aerial vehicles have various sensors, including high-resolution cameras, multispectral and hyperspectral sensors, and LiDAR (Light Detection and Ranging) [3]. These enable them to capture detailed imagery and generate accurate 3D models of forest canopies. This data is crucial for assessing vegetation cover, tree density, and biomass estimation, essential metrics for effective forest management.

UAVs also play a critical role in monitoring forest health. They can detect early signs of disease, pest infestations, or drought stress across large areas with precision that ground-based observations cannot match [4]. The ability to survey vast areas frequently and at a lower cost than satellite imagery or manned aircraft surveys makes UAVs particularly useful for longitudinal studies, where changes in forest health and growth patterns must be monitored over time.

Regarding conservation efforts, drones provide essential data for habitat assessment, aiding in biodiversity protection by identifying areas of ecological significance that require conservation or restoration [5]. UAVs also help map and monitor deforestation and illegal logging activities, providing enforcement agencies with the information needed to take timely action.

Another significant advantage of using UAVs in forestry is their ability to operate in various weather conditions and terrains, offering Flexibility often crucial in emergencies such as forest fires. By providing real-time data and imagery, UAVs help in the rapid assessment of fire damage, the identification of hotspots, and the monitoring of post-fire recovery, thereby playing a pivotal role [6] in disaster management and response strategies.

However, the deployment of UAVs in forest monitoring is challenging. Issues such as data management and analysis, privacy concerns, and the need for technical expertise in operating advanced UAV systems and interpreting the collected data are some of the hurdles that must be addressed. Additionally, regulatory frameworks governing UAV flights, particularly in sensitive or protected areas, must be navigated carefully to harness the full potential of this technology in forest conservation efforts [7].

The exponential increase in data collected from UAVs necessitates robust automated image analysis systems to process and interpret vast amounts of information efficiently. Automated image analysis plays a fundamental role in transforming raw data into actionable insights [8], which is critical for timely and informed decision-making in forest management.

Automated image analysis systems utilise sophisticated algorithms, including machine learning and deep learning, to process high-resolution images for various applications such as species identification, counting individual trees, assessing tree health, and mapping forest cover. These systems are designed to handle the complexities of analysing natural environments, where variability in lighting, weather conditions, and seasonal changes can significantly affect image quality and the accuracy of the analysis.

Integrating artificial intelligence (AI) in image analysis enhances the speed and accuracy of data processing [9]. It enables the identification of subtle changes in vegetation that may not be visible to the human eye. For instance, changes in the colour or texture of foliage detected through image analysis can indicate disease or water stress before severe damage occurs, allowing for proactive management measures.

Moreover, automated image analysis supports the management of the vast datasets generated by UAVs, streamlining the process of data sorting, tagging, and storing [10]. This is crucial for maintaining historical data, which is valuable for trend analysis and long-term monitoring objectives.

The necessity of automated image analysis extends beyond just data processing; it is integral to making UAV technology a scalable and practical tool for forest management [11]. As the technology evolves, the development of more advanced image analysis tools will likely focus on improving the granularity of data

interpretation and the usability of the analysis outputs, thereby broadening the scope of UAV applications in forestry and beyond [12].
This introduction sets the stage for a detailed exploration of various software products designed for UAV image analysis, assessing their capabilities and performance in meeting the complex demands of forest monitoring and management.

2. Overview of Key Software Tools for UAV Image Analysis

Integrating UAV technology with sophisticated image analysis software has significantly enhanced the capacity for detailed and scalable monitoring across various sectors, particularly in forestry. Here is an overview of some of the leading software products currently used for processing UAV-derived imagery:
Pix4Dmapper offers a comprehensive photogrammetry suite, converting UAV-captured imagery into accurate, georeferenced 2D maps and 3D models [13]. It is particularly valued for its application in generating vegetation indices such as the Normalised Difference Vegetation Index (NDVI), which aids in monitoring plant health. The software supports extensive dataset processing, a critical feature for managing large forest or agricultural land expanses. Cloud-based processing capabilities allow users to handle data-intensive tasks without relying on local computational power.
DroneDeploy provides a user-friendly interface that facilitates real-time mapping and on-the-fly analysis. It is suitable for a range of industries, including agriculture and construction [15]. The platform offers comprehensive tools for creating high-resolution orthomosaics and 3D models, coupled with robust data analysis features, such as plant health monitoring, which leverages various vegetation indices.
Agisoft Metashape is known for its high precision in creating detailed 3D reconstructions and terrain models from images captured at multiple angles. The software supports various cameras and UAV systems, making it versatile for RGB and multispectral image processing. This Flexibility is essential for projects that require detailed analysis of complex environments.
Trimble UASMaster integrates with various UAV platforms to offer a detailed suite for photogrammetric processing, including generating point clouds, orthophotos, and sophisticated surface models [16]. It provides customisable workflows that adapt to geospatial projects, making it suitable for straightforward and complex mapping tasks.
Correlator3D by SimActive is designed to meet the needs of professionals who need to process large datasets quickly into precise orthomosaics and DEMs [17]. Its capability to handle high volumes of data efficiently makes it ideal for projects that require a quick turnaround without compromising on data accuracy.
Global Mapper is a GIS software that excels in handling various spatial datasets, including UAV and satellite imagery [18]. It offers extensive tools for spatial data analysis, terrain visualisation, and advanced processing capabilities such as watershed delineation and contour generation.
ENVI OneButton simplifies the image processing workflow by automating the steps from data import to the final production of orthomosaics and elevation models [19]. It is designed to be user-friendly and allows individuals without extensive remote sensing expertise to produce professional-quality maps and models.
Propeller Aero delivers solutions for mining, construction, and earthworks projects. It provides accurate 3D mapping tools that assist in calculating volumes, monitoring progress, and conducting site surveys efficiently [20].

Maps Made Easy lets users convert drone-captured images into detailed maps and models. The platform is praised for its ease of use and effectiveness in producing accurate geospatial data, which can be employed for various applications, from environmental conservation to urban planning.

Each of these software platforms is developed with specific user needs in mind, ensuring a tool is available for virtually any type of UAV-based mapping and analysis requirement. This diversity in functionality and application underscores the dynamic nature of UAV technology and its growing importance in various fields.

3. Methods

The methodology for evaluating UAV image analysis software integrates a structured approach, leveraging quantitative and qualitative assessments across various critical criteria. Each criterion is weighted according to its practical significance, ensuring that the most crucial aspects significantly influence the overall evaluation.

Accuracy and Precision (20%): This fundamental aspect is evaluated by conducting field tests to compare software outputs against known geospatial measurements. Accuracy is crucial, particularly in sectors like forestry management, urban planning, and environmental monitoring, where spatial precision directly impacts decision-making. The high weighting reflects the critical nature of reliable, precise geospatial data.

Functionality and Features (18%): The scope of functionalities is assessed through a comprehensive checklist that includes support for various sensor data types, the capability to compute vegetation indices like NDVI, and tools for advanced 3D modelling. This criterion's substantial weight underscores the importance of versatility and comprehensive feature sets in adapting the software for various projects.

Processing Speed (15%): Time efficiency is tested by processing UAV image datasets of varying sizes and complexities. Processing speed is essential in scenarios requiring quick data turnaround, making it a significant factor in operational efficiency and project cost management.

Ease of Use and User Interface (10%): User experience surveys measure the software's intuitiveness and the ease with which new users can become proficient. A user-friendly interface enhances productivity and broadens the software's accessibility, which is essential for organisations looking to scale operations efficiently.

Integration and Compatibility (10%): This criterion assesses how well each software integrates with other UAV platforms and GIS tools. This is crucial for maintaining seamless workflows in diverse technological environments. Working smoothly with various systems without extensive modifications is vital for operational coherence.

Cost and Licensing (10%): Financial aspects are critically analysed, comparing initial costs, subscription fees, and the Flexibility of licensing terms. This analysis ensures that users find the software economically viable, reflecting its value for money in long-term deployments.

Scalability (7%): Software is evaluated on its ability to handle increasing data volumes without performance degradation. Scalability is essential for long-term usability as project scopes and data requirements grow.

Customisation and Flexibility (5%): The potential for software customisation through scripting or plugins is evaluated. This is important for users who need to tailor tools to specific project requirements. This Flexibility can significantly enhance the software's utility in specialised applications.

Data Security and Privacy (3%): This criterion is especially critical for cloud-based solutions. It involves auditing the software's security features, including data encryption and compliance with data protection regulations, to ensure user data is safeguarded effectively.

Support and Community (2%): Support ticket responses and community engagement metrics assess the quality of customer support and the vibrancy of the user community. Effective support and a dynamic community can greatly enhance user satisfaction and software utility.

To calculate the final score for each UAV image analysis software, we start by assessing each software against a set of predefined criteria such as accuracy, functionality, processing speed, and ease of use. Each software is rated on these criteria using a scale from 0 to 10, where 0 represents poor performance and 10 indicates excellent performance.

Each score obtained is then multiplied by the respective weight assigned to that criterion, reflecting its importance in the overall performance of the software. For example, if a software scores 8 on 'Accuracy and Precision' – a criterion weighted at 20% – the weighted score for this aspect would be 8 x 0.20 = 1.6. This process is repeated across all criteria, applying specific weights such as 18% for functionality and features, 15% for processing speed, etc.

After multiplying each score by its corresponding weight, the weighted scores for all criteria are summed to obtain the software's final score. This aggregated score provides a comprehensive quantitative measure of the software's overall capabilities, considering the varying importance of each evaluation criterion. This methodology ensures a balanced and thorough comparison of software tools, enabling users to make well-informed decisions based on specific operational needs and priorities.

4. Results

The comprehensive evaluation of ten UAV image analysis software tools revealed notable variations in performance across a spectrum of critical criteria. These findings are based on a detailed assessment, where each software was scored on aspects such as Accuracy and Precision, Functionality and Features, and Processing Speed, among others. The detailed scores for each criterion are presented in Table 1, providing a clear overview of how each software performed in individual areas.

Table 1: Performance Evaluation Scores of UAV Image Analysis Software Across Key Criteria

Software	Accuracy & Precision	Funcionality & Features	Ease of Use & UI	Processing Speed	Integration & Compatibility	Cost & Licensing	Scalability	Customisation & Flexibility	Data Security & Privacy	Support & Community
Pix4Dmapper	8,7	9,2	8,0	8,3	8,5	7,9	7,8	7,6	7,4	7,5
DroneDeploy	8,4	8,6	9,5	8,9	8,1	7,5	8,0	7,0	7,7	88,2
Agisoft Metashape	9,3	8,1	7,5	7,9	7,3	7,0	8,1	7,8	7,2	7,0
Trimble UASMaster	8,6	8,4	7,8	8,0	8,8	7,8	7,5	7,3	7,0	7,1
Correlator3D	8,1	8,3	7,4	9,1	8,3	7,3	8,3	6,9	7,1	6,8
Global Mapper	7,9	8,0	8,2	7,7	7,5	7,4	7,2	7,1	7,5	7,6
ENVI OneButton	8,0	7,5	8,5	7,6	7,9	7,0	7,4	6,7	7,8	7,9
Propeller Aero	7,5	7,7	7,6	8,0	7,8	7,1	7,0	6,5	7,0	7,3
Maps Made Easy	7,8	7,9	8,3	7,8	7,6	7,5	7,4	6,8	7,3	7,7

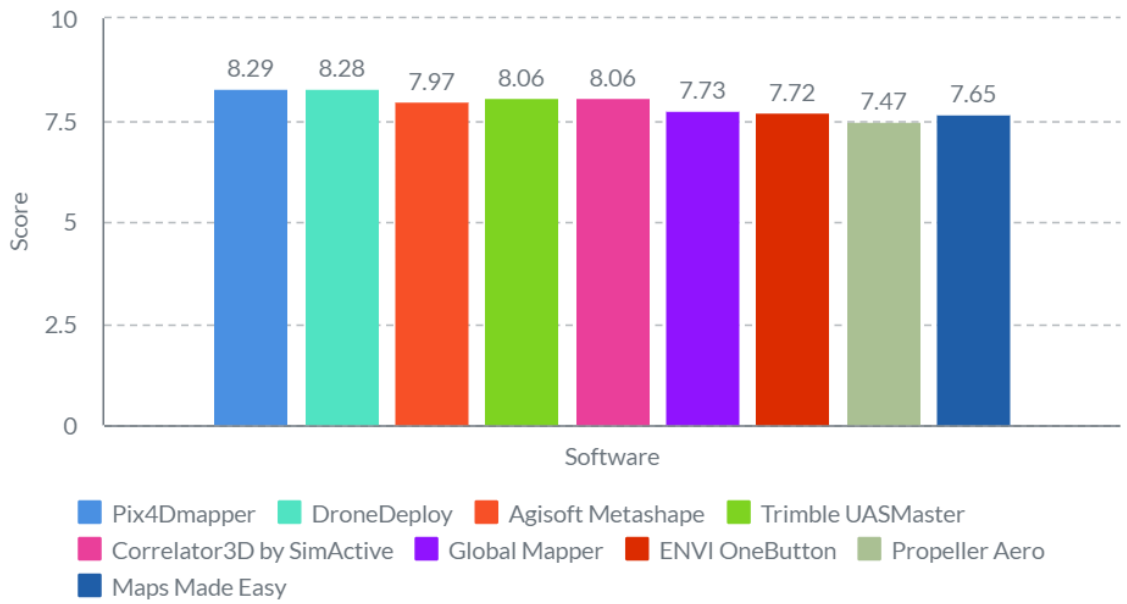
Pix4Dmapper emerged with a strong overall score, showcasing its robust capabilities, particularly in Functionality and Features, where it scored 9.2. This score reflects its advanced analytical tools suitable for complex image processing tasks. Its high score in Accuracy and Precision, 8.7, also highlights its reliability in producing detailed and precise geospatial data.

DroneDeploy excelled in Ease of Use and User Interface, scoring an impressive 9.5, making it highly accessible and user-friendly. Additionally, its processing speed 8.9 suggests it is well-suited for projects requiring quick data turnover without compromising the quality of outputs.

Agisoft Metashape, scoring the highest in accuracy and precision at 9.3, is exceptionally reliable for tasks demanding high fidelity in data interpretation, which is crucial for accurate mapping and modelling projects.

Correlator3D by SimActive demonstrated its efficiency with a top score of 9.1 in Processing Speed, indicating its capability to handle extensive datasets swiftly, a vital attribute for large-scale and time-sensitive operations.

Figure 1: Evaluation Summary



The analysis also included software such as **Trimble UASMaster**, which showed excellent Integration and Compatibility, scoring 8.8, indicating its seamless operational integration with various UAV systems and GIS platforms, enhancing workflow continuity.

Other software, such as **Global Mapper**, **ENVI OneButton**, **Propeller Aero**, and **Maps Made Easy**, provided consistent results across various criteria, underlining their effectiveness in specific niches and general applicability for diverse project requirements.

For a visual representation of these evaluations, refer to the diagram (Figure 1), which graphically displays the final scores for each software, illustrating their relative strengths and weaknesses in a clear and comparative format.

5. Conclusions

The detailed analysis of UAV image analysis software across various operational criteria has pinpointed specific capabilities and limitations of each tool, offering a targeted perspective for potential users. This assessment facilitates strategic decision-making for organisations and individuals aiming to optimise their geospatial data collection and analysis operations.

Firstly, the high performance of Pix4Dmapper in functional richness suggests its suitability for complex projects requiring detailed data analysis and advanced processing capabilities. Organisations involved in precision agriculture, urban planning, or environmental monitoring might find Pix4Dmapper an invaluable asset due to its comprehensive toolset.

DroneDeploy's leading score in user interface efficiency indicates its appropriateness for projects that require fast onboarding and ease of use. This could potentially reduce training time and enhance productivity for teams with varied technical skills. Its intuitive design could benefit small to medium enterprises or educational settings where simplicity and quick data handling are prioritised.
The superior accuracy of Agisoft Metashape positions it as a preferred choice for scientific research and applications where data precision is paramount. It might include cultural heritage preservation, where exact reconstruction of artefacts and sites is essential, or in forestry, where detailed canopy analysis is required.
Correlator3D by SimActive, excelling in processing speed, would be particularly effective in scenarios demanding rapid turnaround, such as emergency response or real-time environmental monitoring. Its ability to swiftly process large datasets can significantly enhance operational responsiveness during critical events.
Furthermore, the balanced capabilities of software like Global Mapper and ENVI OneButton underline their applicability as reliable, all-around tools for various GIS tasks. These platforms serve well in governmental and educational institutions where diverse functionality across multiple projects is needed.
This focused evaluation underscores the importance of aligning software selection with specific project demands and operational environments. Users can significantly enhance their operational efficiency and data analysis outcomes by choosing a tool that closely matches their needs, ensuring they leverage the most effective technology for their specific geospatial tasks. This strategic approach optimises resource allocation and maximises the potential for successful project outcomes.

6. Discussion

This analysis illuminates the nuanced landscape of UAV image analysis software, reflecting a convergence of technological advancement and user-centric design. One of the pivotal discussions emerging from this study is the trade-off between comprehensive functionality and user accessibility. Advanced tools like Pix4Dmapper offer extensive capabilities but also demand a steeper learning curve, which may not align with the needs of all user groups. Conversely, DroneDeploy exemplifies how streamlined interfaces can enhance user engagement and reduce operational downtime, albeit sometimes at the expense of less comprehensive feature sets.
Another significant consideration is adapting software tools to rapidly evolving hardware advancements. The interaction between software and the latest UAV technologies, such as increased sensor resolution and new spectral imaging capabilities, necessitates ongoing software updates and development. This dynamic challenges software developers to keep pace with hardware innovations, ensuring that software capabilities fully leverage the data quality and variety provided by modern UAVs.
The scalability of software in large-scale operations also presents a critical discussion point. Tools like Correlator3D demonstrate that high processing speeds can mitigate data bottlenecks in extensive survey projects. However, this necessitates robust computational resources, which may only be readily available in some operational contexts, particularly in resource-limited settings.
Furthermore, the discussion extends to integrating UAV software with broader GIS and remote sensing workflows. Software tools' ability to seamlessly integrate with existing GIS platforms and data formats is crucial for ensuring continuity and efficiency in data processing pipelines. Software like Trimble UASMaster, which exhibits high integration capabilities, illustrates the potential for UAV image analysis

tools to act not merely as standalone solutions but as integral components of comprehensive geospatial analysis ecosystems.
Lastly, the evolving regulatory and security landscape surrounding UAV operations and data handling must be addressed. As UAVs become ubiquitous in various sectors, software tools must provide enhanced data security measures and ensure compliance with international data privacy laws and regulations. This aspect is especially pertinent in sectors like environmental monitoring and urban planning, where data sensitivity can be high.
These discussions underscore the importance of continuous innovation and adaptation in UAV image analysis software development. Technological capabilities must be aligned with user needs and regulatory requirements to maximise the utility and applicability of these tools in real-world scenarios.

7. References

1. Liu, T., Sun, Y., Wang, C., Zhang, Y., Qiu, Z., Gong, W., ... & Duan, X. (2021). Unmanned aerial vehicle and artificial intelligence revolutionizing efficient and precision sustainable forest management. *Journal of Cleaner Production*, *311*, 127546.
2. Ecke, S., Dempewolf, J., Frey, J., Schwaller, A., Endres, E., Klemmt, H. J., ... & Seifert, T. (2022). UAV-based forest health monitoring: A systematic review. *Remote Sensing*, *14*(13), 3205.
3. Zhou, G., Zhou, X., Song, Y., Xie, D., Wang, L., Yan, G., ... & Wang, H. (2021). Design of supercontinuum laser hyperspectral light detection and ranging (LiDAR)(SCLaHS LiDAR). *International journal of remote sensing*, *42*(10), 3731-3755.
4. de Castro, A. I., Shi, Y., Maja, J. M., & Peña, J. M. (2021). UAVs for vegetation monitoring: Overview and recent scientific contributions. *Remote Sensing*, *13*(11), 2139.
5. Librán-Embid, F., Klaus, F., Tscharntke, T., & Grass, I. (2020). Unmanned aerial vehicles for biodiversity-friendly agricultural landscapes-A systematic review. *Science of the total environment*, *732*, 139204.
6. Mohsan, S. A. H., Khan, M. A., Noor, F., Ullah, I., & Alsharif, M. H. (2022). Towards the unmanned aerial vehicles (UAVs): A comprehensive review. *Drones*, *6*(6), 147.
7. Bayomi, N., & Fernandez, J. E. (2023). Eyes in the Sky: Drones Applications in the Built Environment under Climate Change Challenges. *Drones*, *7*(10), 637.
8. Li, P., & Khan, J. (2023). Feature extraction and analysis of landscape imaging using drones and machine vision. *Soft Computing*, *27*(24), 18529-18547.
9. Irrgang, C., Boers, N., Sonnewald, M., Barnes, E. A., Kadow, C., Staneva, J., & Saynisch-Wagner, J. (2021). Towards neural Earth system modelling by integrating artificial intelligence in Earth system science. *Nature Machine Intelligence*, *3*(8), 667-674.
10. Shukla, A., & Jain, K. (2020). Automatic extraction of urban land information from unmanned aerial vehicle (UAV) data. *Earth Science Informatics*, *13*(4), 1225-1236.
11. Torresan, C., Benito Garzón, M., O'grady, M., Robson, T. M., Picchi, G., Panzacchi, P., ... & Kneeshaw, D. (2021). A new generation of sensors and monitoring tools to support climate-smart forestry practices. *Canadian Journal of Forest Research*, *51*(12), 1751-1765.
12. Vélez, S., Martínez-Peña, R., & Castrillo, D. (2023). Beyond vegetation: A review unveiling additional insights into agriculture and forestry through the application of vegetation indices. *J*, *6*(3), 421-436.
13. *Pix4Dmapper: Professional photogrammetry software for drone mapping*. (n.d.). Pix4D. https://www.pix4d.com/product/pix4dmapper-photogrammetry-software

14. *DroneDeploy Aerial: drone mapping software | Drone Surveying*. (n.d.). https://dronedeploy.com/product/dronedeploy-aerial
15. *Installer*. (2019). Agisoft.com. https://www.agisoft.com/downloads/installer/
16. *Trimble Inpho UASMaster | Office Software*. (n.d.). Geospatial.trimble.com. Retrieved June 2, 2024, from https://geospatial.trimble.com/en/products/software/trimble-inpho-uasmaster
17. Inc, S. (n.d.). *Correlator3D Mapping Software | SimActive*. Www.simactive.com. Retrieved June 2, 2024, from https://www.simactive.com/correlator3d-mapping-software-features
18. *Global Mapper*. (n.d.). Blue Marble Geographics. https://www.bluemarblegeo.com/global-mapper/
19. *Image Processing & Analysis Software | Geospatial Image Analysis Software | ENVI®*. (n.d.). Www.nv5geospatialsoftware.com. https://www.nv5geospatialsoftware.com/Products/ENVI
20. *Drone Mapping Software*. (n.d.). Propeller. https://www.propelleraero.com/
21. Easy, M. M. (n.d.). *Maps Made Easy - Home*. Www.mapsmadeeasy.com. https://www.maps-madeeasy.com/