AN OVERVIEW OF GEOPROCESSING AND EXPORT OPTIONS FOR CREATING 3D GIS MODELS USING DRONE2MAP

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***Abstract**: In this article the main topic of interest is to explore the processing possibilities offered by the latest version of Drone2Map. At the same time, we want to highlight the ways of sharing the 2D and 3D products obtained, but also the means of their subsequent analysis in the established GIS environment. One of the major advantages identified is primarily the interoperability of Drone2Map - ArcGIS Online – ArcGIS Pro.*

***Keywords:** UAV, Drone2Map, ArcGIS Pro, ArcGIS Online*

1. Introduction

Lately, in particular, there has been an evolution of easy-to-use UAV drones, but also of image processing software products. Due to them, the use of UAVs greatly reduces the time allocated to obtain complex studies. Orthomosaics is particularly important because it provides the basis for cadastral mapping and subsequent visual interpretation, manual digitization, mapping or element detection procedures.

There are different ways to model elevation in GIS, like Digital Elevation Models (DEM), Digital Surface Models (DSM), Digital Terrain Models (DTM) and Triangular Irregular Networks (TIN) [14]. A DSM captures the natural and built features being used especially in hydrology, soils and land use planning. In some approaches, a DTM is actually synonymous with a DEM. A DTM is simply an elevation surface representing the bare earth referenced to a common vertical datum. In this subject are some different viewpoints, for exampe in the US and other countries, a DTM has a slight different meaning, as a vector data set, composed of regularly spaced points and natural features such as ridges and breaklines. A DTM augments a DEM by including linear features of the bare-earth terrain. Triangular Irregular Networks are vector-based lines with three-dimensional coordinates. Using Delaunay triangulation, TINs are good when points are irregular distrubuted geographically. According with Esri’s GIS dictionary, Delaunay triangulation is a technique for creating a mesh of contiguous, nonoverlapping triangles from a dataset of points, and each triangle's circumscribing circle contains no points from the dataset in its interior. [15]

ArcGIS is a comprehensive imagery platform and processing workflow using data acquired by drones is integrated into the complete ArcGIS platform. [9]

Drone2Map for ArcGIS [16] is a desktop application that turns raw, still imagery from drones into orthorectified mosaics, terrain models, point clouds, 3D meshes, etc. Drone2Map Use Cases are:

- 2D Mapping: overlapping, nadir orthomosaic, DEM, DSM 3D point cloud, mesh – nadir (vertical) images.

- 3D Mapping: overlapping, nadir and oblique orthomosaic, DEM, DSM 3D point cloud, mesh - nadir (vertical) and oblique (in direction of arrow) images. The 3D point cloud allows the analysis of natural and man-made spatial objects, including volumetric measurements, detection of changes, lines of sight and obstacles.
- Inspection Mapping: overlapping, high oblique images, annotation, attribution visualization – concentric high oblique images (different altitudes).

It is also possible to perform a rapid processing to validate collection.

Regarding the quality, in figure 1 we have a schema to overview of quality metrics and influencing parameters (adapted from [10]). Reliability is directly linked with the representation of the real world, being highly dependent on the image quality.

Spatial resolution is composed by two different aspects:

- GSD - ground sampling distance = the distance between two consecutive pixel centers measured on the ground and is determined by the sensor specifications and the flying height, being affected by the sensor's pixel size and the image scale.
- GRD - ground resolving distance = the size of the smallest element distinguishable on an acquired image, being affected by aspects such as lens quality, lens aperture being used, and image blurriness.

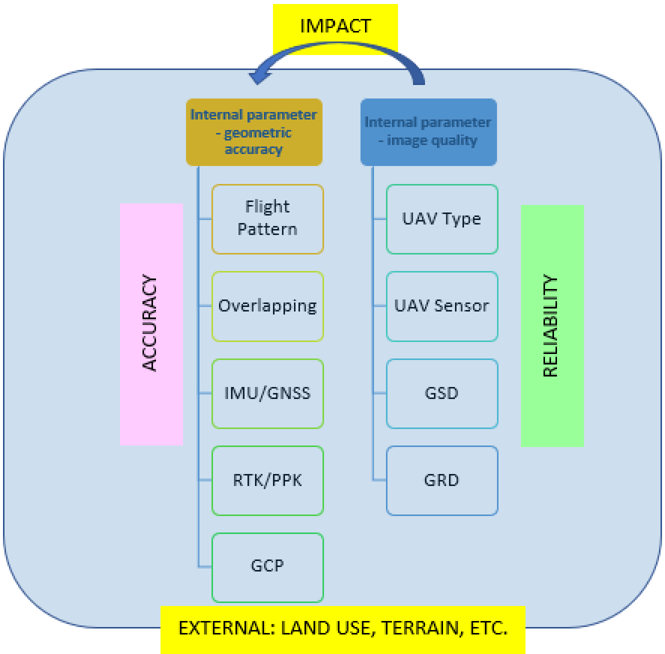


Figure 1 - Schematic overview of quality metrics and influencing parameters (adapted from [10])

2. Geoprocessing Options Overview

In the scientific literature are emphasized software options comparison [3], [4], [13] and user needs to be able to assess the utility of the software capabilities on offer in order to select the most effective and economic for their applications.

According to [3], to benchmark between software is particularly difficult because there doesn't exist harmonised main points for project input and project output and software producers do not reveal details of their algorithmic processing strategy for sampling, colour or texture blending etc. In figure 2 are emphasized the key essential features for UAV projects.

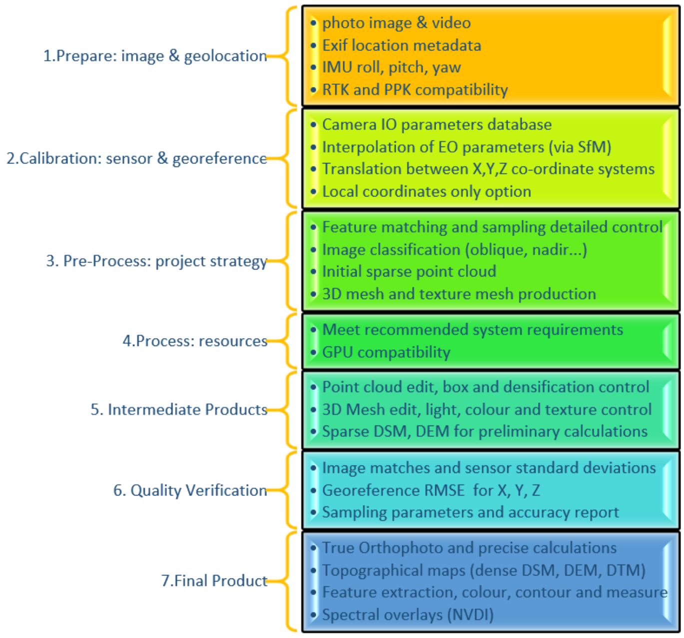


Figure 2 - Key Essential Features for UAV projects (adapted from [3])

Using Drone2Map for ArcGIS is possible to control the way for extracting keypoints, requiring longer processing time, usually to obtain GIS products, or quickly verifying the collection in the field. The initial processing is composed by keypoints image scale, matching image pairs, matching strategy, targeted number of keypoints, calibration method and rematch. The image scale value can be set at 2, 1, 1/2,1/4, 1/8, according with overlapping degree, size of images that can be used to speed up processing workflow, needed degree of accuracy, the numbers of features to be extracted. [11]

Another useful option is selecting which pairs of images are matched for aerial grid or corridor flight paths, free-flight paths or terrestrial images, or based on the time they were taken.

It can be also used the triangulation process for geolocated images, or a relative distance between consecutive images. It is possible to set a degree for image similarity and a maximum number of image pairs with similar image content. In case of multiple flights with different camera, in the same area, it can be used the time of flight to match the images.

An important processing issue is the matching strategy, involving to set how images are matched. To obtain more consistent matches is used geometry content of the clearest matches between images, not just most similar features. The number of target keypoints can be used as automatic or custom, allowing to have a lower number of keypoints. According with [11], when extracting the keypoints per image, an internal scoring is assigned to them, having the purpose that based on this scoring, the best keypoints to be selected.

If ground control points (GCPs) are not included in the project, then output coordinate system and vertical reference can be modified, although based on GCP is determined the output coordinate system and vertical reference for Drone2Map output products. For example, an XY coordinate system of WGS84, Drone2Map output products are created using an XY coordinate system of the relevant UTM zone. In case without GCPs, the reference system is determined based on the images. [11]

The density of the point cloud is obtained up to the image scale (with a high impact in RAM needed, processing time and the number of 3D generated points), the point density, point cloud densification and the number of matches. An optimal setting means that if Image

Scale is set to 1/2 (half image size), one 3D point is computed every 4/(0.5) = 8 pixels of the original image. For the minimum number of matches, usually a 3D point is correctly reprojected in at least three images. This can be increased or decreased by setting a different number of images in which is needed to have a reprojected point. By increasing the value at 6 images, it is obtained
a higher quality of the point cloud, but a lower noise. It is useful to set the limit camera depth automatically to avoid the reconstruction of the objects from the background.

The resolution to generate the orthomosaic can be set as default, using that of the source imagery, or set a defined value in cm or pixel for the GSD. The tiles can be merged to be added to the map as a 2D product.

To obtain the DSM raster product, the available methods are IDW and triangulation (faster, useful for agricultural fields, but not recommended for buildings). By choosing a filter, can be defined and applied parameters to the point cloud : noise filter and surface smoothing. For DTM can be set the hillshade option and changing the resolution value. The contour lines can be generated for DTM when the area is covered by buildings or other objects as the objects are filtered out for the DTM generation. The contour lines can be generated for raster DSM if the raster DTM is not generated or if the DTM tiles are not merged, using this option when the area is not covered by buildings or other objects as the objects affect the contour lines based on the DSM.

The crop index products are Normalized Difference Vegetation Index (NDVI), Green NDVI and Normalized Difference Red Edge. NDVI is built up from a combination of visual red light and near-infrared (NIR) light. NDRE uses a combination of NIR light and a frequency band that sits on the transition region between visual red and NIR light, being useful for insighting into permanent or later stage crops, being able to measure further down into the canopy. The analysis outputs (figure 3) are including also TSAVI (Transformed Soil Adjusted Vegetation Index), MSAVI (Modified Soil Adjusted Vegetation Index).

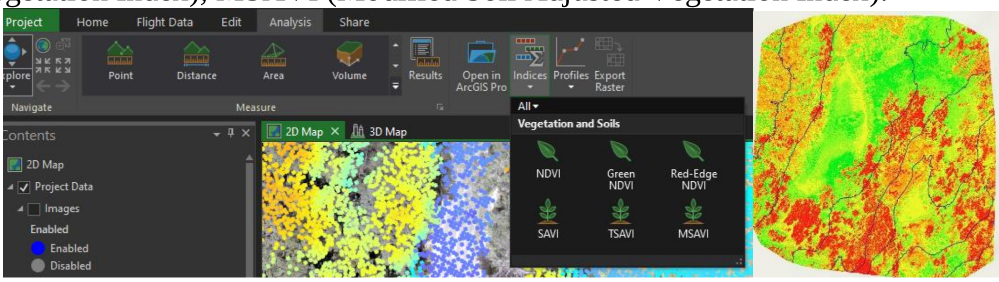


Figure 3 – NDVI and other indices for analysis

For the outputs as 3D products there are the following options: point clouds as LAS, zLAS, PLY, XYZ. [5] A lidar zLAS file is an Esri's optimized LAS format with X,Y,Z position and color information for each point of the point cloud. If there are many points in the point cloud are generated several tiles, but using the option Merge Tiles it is possible to produce a single file with all the points. The option for the point cloud classification can be used for the DTM generation and the DTM is improved.

Another important option is focused on creating textured meshes, because a level-of-detail (LoD) mesh allows adjusting the resolution and number of levels of detail for your mesh.

The level of detail (LOD) mesh is composed by multiple levels of detail, decreasing the complexity of the model as it is divided into more levels. There is a maximum number of 20000 triangles that can be generated for each level of details and a maximum 7 different levels of detail. Texture quality of the 3D mesh is linked with resolution of the texture. LoD mesh formats in Drone2Map are the following: OSGB, Scene Layer Package, OBJ, FBX, DXF, PLY, 3D PDF inluding a logo. 3D PDF represents a PDF file containing a 3D model of the 3D textured mesh, with the texture size of the 3D textured mesh of max 2000x2000 pixels.

3. Results on a Case Study

An open access data set Greg 1 and 2 Reservoir with GCP [12], including ground control points, was used for the case study, to emphasize the possibilities for processing in Drone2Map. According to [12], it was used a Phantom 3 Advanced drone to collect imagery for digital elevation model and orthomosaic generation of the site. GCP were surveyed with a Trimble 5800 and used during the image processing. There were acquired 189 images in September 2019. In figure 4 are Camera Parameters, in figure 5 the processing log (extract) in Drone2Map, in figure 6 GCP and images displacement and in figure 7 the obtained products (ortho, DSM, DTM).

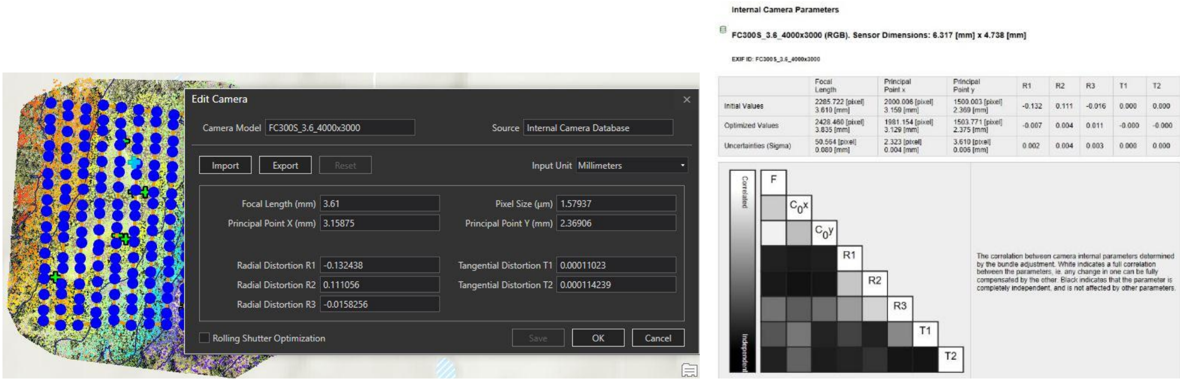


Figure 4 – Camera Parameters

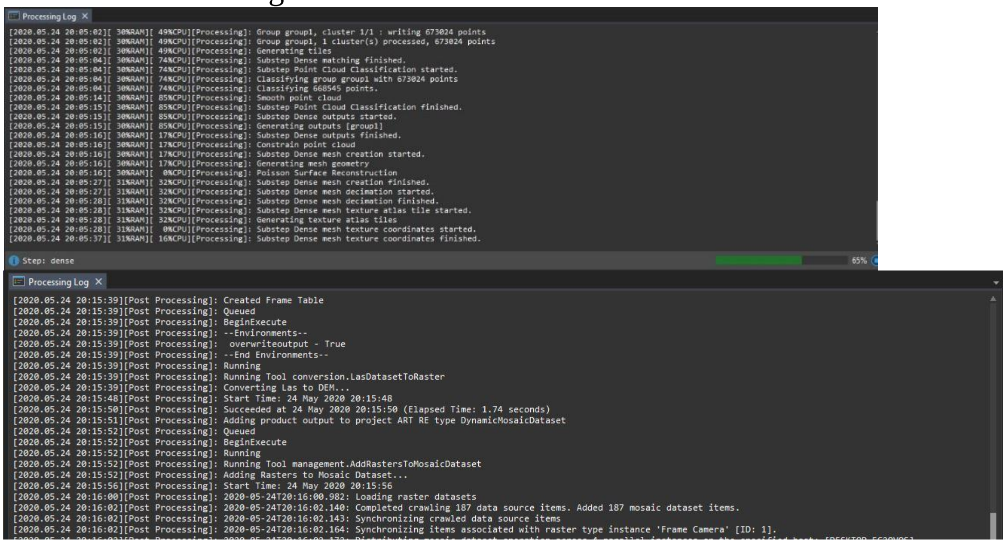


Figure 5 – Log Processing (extract)

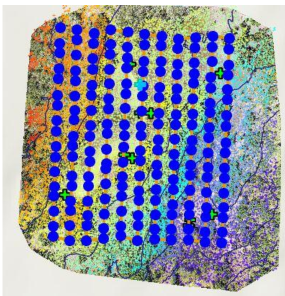


Figure 6 – GCP and Images Displacement

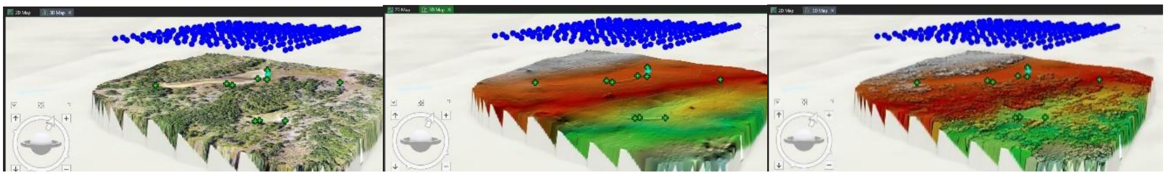


Figure 7 - Obtained Products

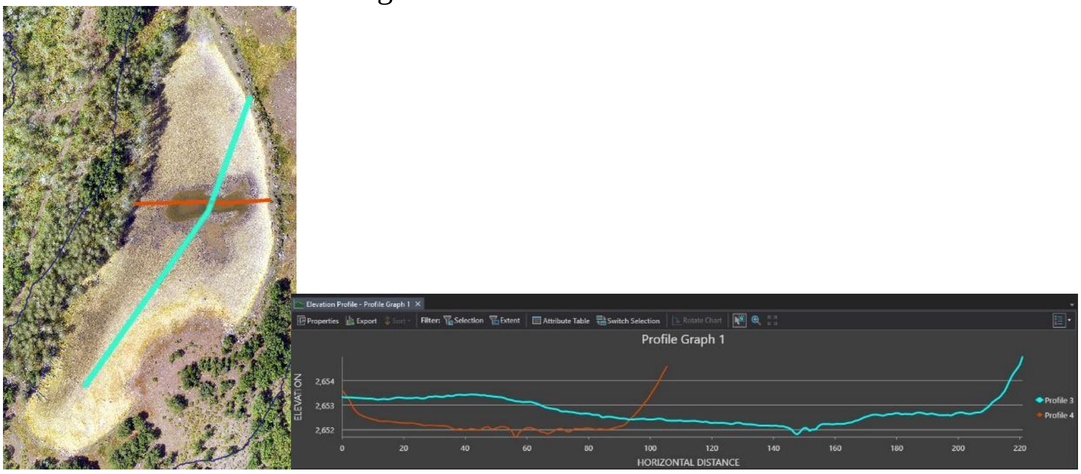


Figure 8 – Obtaining Profiles

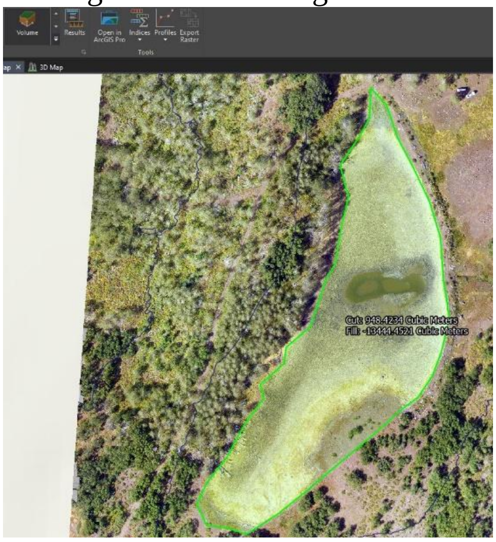
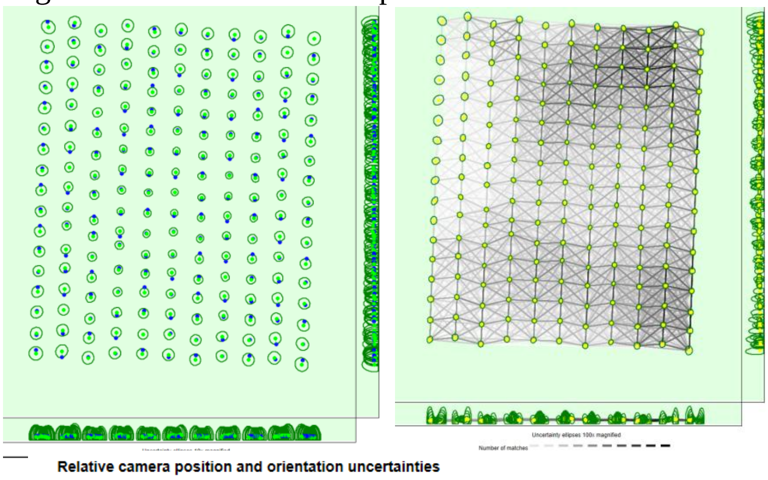


Figure 9 – Calculate Volumes

4. Processing Report and Sharing Options

In figure 8 (left side) is highlighted Offset between initial (blue dots) and computed (green dots) image positions. Dark green ellipses indicate the absolute position uncertainty of the bundle block adjustment result. It is also presented the offset between the GCPs initial positions (blue crosses) and their computed positions (green crosses) in the top-view (XY plane), front-view (XZ plane), and side-view (YZ plane). On the right side are computed image positions with links between matched images, in which the darkness of the links indicates the number of matched 2D keypoints between the images. Bright links indicate weak links and require manual tie points or more images. Dark green ellipses indicate the relative camera position uncertainty of the bundle block adjustment result.

In projects with GCPs, a large sigma (figure 10) can signify that some areas of the project are less accurately reconstructed and may benefit from additional GCPs. [11] There are emphasized the mean uncertainty in the X/Y/Z direction of the absolute camera positions, mean Omega/Phi/Kappa - mean uncertainty in the omega/phi/kappa orientation angle of the absolute camera positions, sigma X/Y/Z - sigma of the uncertainties in the X/Y/Z direction of the absolute camera positions, sigma Omega/Phi/Kappa - sigma of the uncertainties in the omega/phi/kappa angle of the absolute camera positions.



	X [m]	Y [m]	Z [m]	Omega [degree]	Phi [degree]	Kappa [degree]
Mean	0.032	0.036	0.060	0.055	0.048	0.008
Sigma	0.007	0.008	0.036	0.027	0.025	0.002

Figure 10 - Extract from the Processing Report

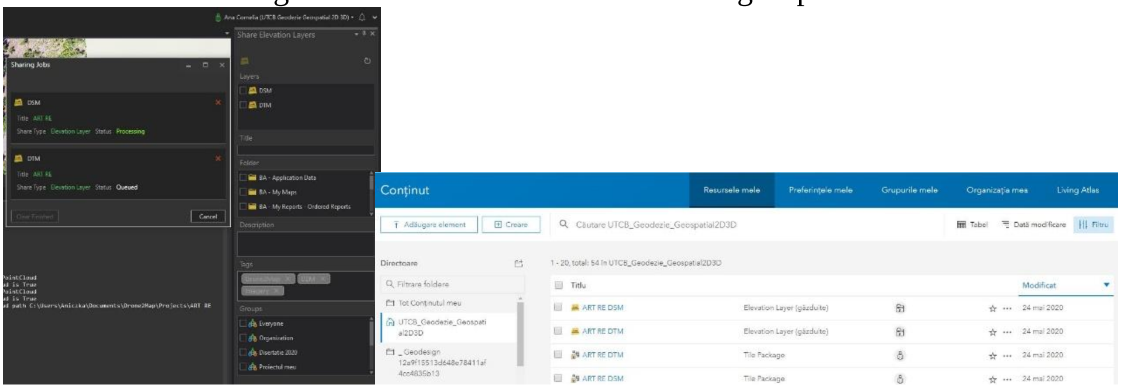


Figure 11 – Sharing Products in ArcGIS Online

Sharing data and information products can be made including by enable access to a dynamic representation of information product as an image service. In ArcGIS Pro it is possible to automate the workflow[5],[6],[8] so that the models obtained are quickly integrated and used.

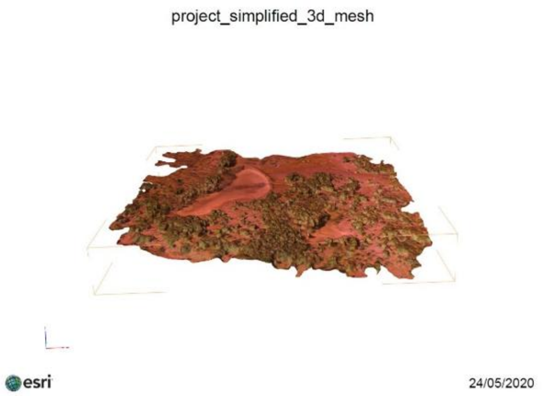


Figure 12 – 3D PDF and Export options

5. Conclusions

The best situation is when the images have enough visual content to be processed, Keypoints Image Scale >1/4 and more than 10,000 keypoints have been extracted per image. In case of fewer than 500 keypoints have been extracted per image, it is needed to increase the overlap.

Some of main advantages of using Drone2Map for ArcGIS are: detecting the drone's camera and sensor parameters and applying the correct defaults, enabling rapid processing; integrated with the ArcGIS technology stack - ArcGIS supports the entire workflow in partnership with Pix4D; supports a wide array of platforms and sensors; processing of large collections of imagery supporting complex use cases, quickly measure volumetrics, integrated to ESRI's core GIS products. This software solution is very useful for Esri GIS users, obtaining fine results of processing both in 2D and in 3D.

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