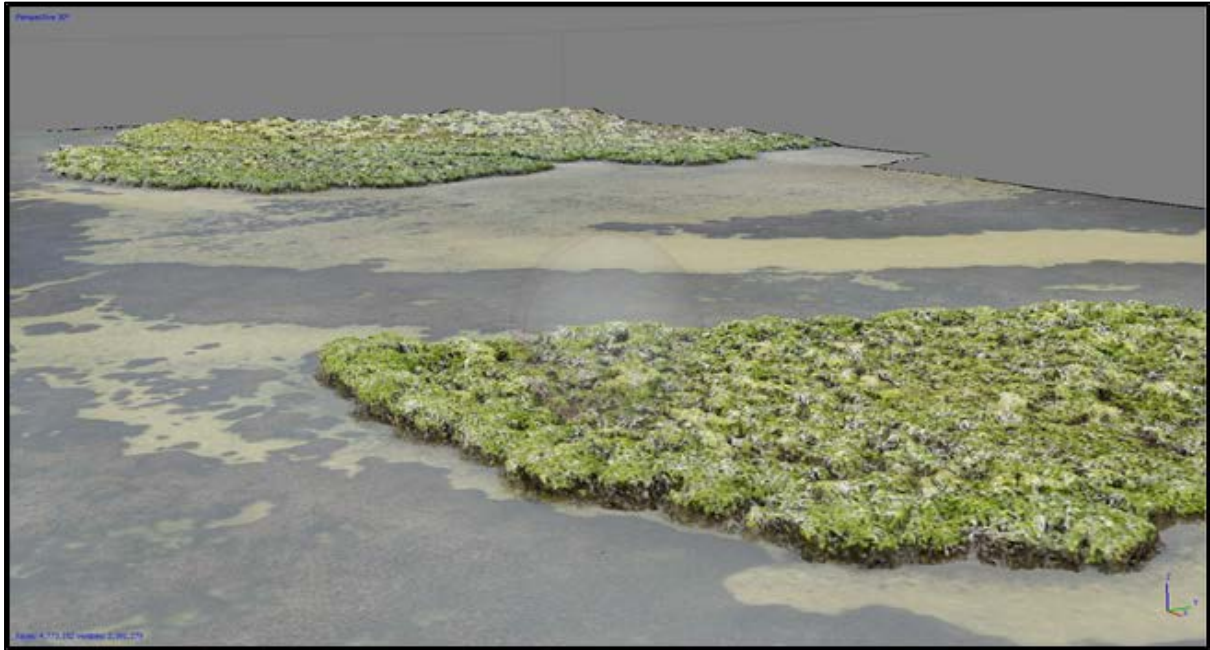


# From pretty pictures to real data, real information and real impact from drones



**A practical manual for mapping seagrass meadows from drone-imagery using open-access software.**

Dr. Javier Leon

Version 1

July 2018



This manual has been developed as a collaboration between University of the Sunshine Coast (USC) and Noosa Integrated Catchment Association (NICA) with support from the Norman Wettenhall Foundation Small Environmental Grants Scheme.

Noosa Shire Council is thanked for granting approval for the drone operation component of this project.

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Author:

Dr. Javier Leon – School of Science and Engineering, University of the Sunshine Coast.

Email: [jleon@usc.edu.au](mailto:jleon@usc.edu.au)

# Foreword

Volunteers have long been engaged in field monitoring of seagrass beds in several locations on the Queensland coast on behalf of Seagrass Watch, an organisation administered by James Cook University. The Noosa Integrated Catchment Association (NICA) has supported this program in the Noosa estuary on behalf of Seagrass Watch since 2006. Seagrass beds in some locations may be accessed relatively easily and reproducible data can be gathered using precisely located waypoints; however, in muddy estuaries there can be problems establishing reliable location markers. The field work is arduous, not without hazards, and considerable numbers of participants must be adequately trained in order that valid data be obtained and processed. Accordingly, it is not always possible to ensure that all appropriate conditions can be met. Moreover, a certain amount of physical disturbance of the monitoring sites during surveys is inevitable.

These issues prompted investigation of the potential of unmanned aerial vehicles (hereinafter referred to as drones) for more easily acquiring accurate maps of distribution of seagrass beds in these more challenging locations. NICA was fortunate in securing a grant from the Norman Wettenhall Foundation that enabled Dr Javier Leon of the School of Science & Engineering, University of the Sunshine Coast, to apply his expertise on drone mapping techniques to the acquisition of usable data on seagrass beds.

People are currently thinking up all sorts of exciting ideas for gathering data with drones for many types of environmental monitoring. So this project provides timely and well-informed but cautionary information on just what is involved in the use of this new technology, not just for seagrass mapping, but for other similar applications in environmental monitoring.

Roger Kelly

for the Management Committee,

Noosa Integrated Catchment Association

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## Introduction

Coastal environments and the ecosystem services they provide are of vital importance to societies as 1.9 billion people globally live within 100 km of the coast. Seagrass meadows provide several ecosystem services, including the provision of habitat that supports commercial and recreational fisheries, nutrient cycling and sediment stabilization.

Vegetated coastal habitats including tidal marsh, mangrove and seagrass, play a significant role globally in sequestering carbon dioxide, yet there is a significant global decline in these habitats due to cumulative impact of human activities and rapid changes in the global climate.

Conservation of existing seagrass meadows is always better than trying to restore them after loss. Either way, successful conservation and restoration of seagrass requires at least baseline knowledge of where seagrass meadows are located, their extent and composition and how/why they change over time. However, these biophysical datasets are seldom available at appropriate spatial and temporal scales due to the inherent challenges of working in coastal settings.

Drones are allowing the acquisition of very-high spatial resolution spatial data (pixel sizes in the order of centimetres) across relatively large areas (100s of hectares) with great flexibility in the timing and frequency of image capture. This effectively bridges the gap between detailed field data collection and synoptic remotely-sensed data and offers an unprecedented opportunity to study and monitor coastal habitats.

This manual has been developed as a simple and practical guide to derive baseline information about seagrass meadows (location and extent) from images acquired with

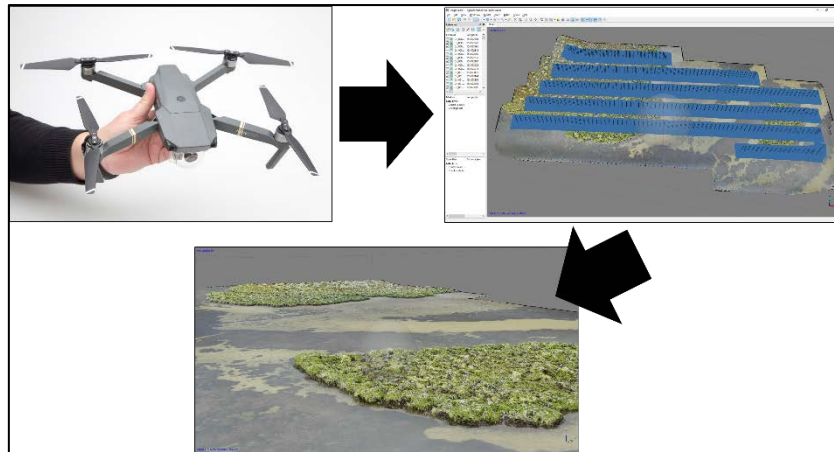
consumer-grade drones. The aim is to provide a basic overview of how to turn individual, overlapping photos into an undistorted image mosaic from which precise measurements can be undertaken.

Many software packages are available commercially to perform such analysis with different levels of complexity. However, this manual outlines the simplest workflow based on free and open-source software to make it more accessible and relevant to community and citizen science groups.

## The workflow

Drones and the sensors/cameras they carry are very diverse in terms of dimensions, weight, operational complexity and cost. There is no “perfect” drone or sensor and selecting the “right” equipment depends on the application or specific problem.

For the purposes of mapping simple attributes of seagrass meadows (i.e. location and extent), consumer-grade commercial drones such as the DJI Phantom 4, Mavic Pro or similar are a suitable option in terms of image quality, ease of operation, weight (under 2 kg), portability, and cost (under A\$~2,000). In particular, the weight **under 2 kg** is of importance due to current flying regulations. For more information about flying regulations in Australia please visit CASA’s website (<https://www.casa.gov.au/aircraft/landing-page/flying-drones-australia>).



**Figure 1: General workflow**

The general workflow to mapping seagrass meadows from drone-imagery consists of 3 main steps (Figure 1):

- Acquiring overlapping images with a drone
- Processing of images using photogrammetric techniques
- Analysis of undistorted image mosaics to measuring location and extent of meadows

### Image acquisition

Drones are ideal tools for mapping, especially hard-to-access areas such as wetlands, because of advances in flight mission control which easily allows programming of flight routes and acquisition of images at pre-determined intervals and locations. The most suitable free flight mission application for DJI drones is **DJI Ground Station Pro** (<http://itunes.apple.com/app/dji-gs-pro/id1183717144?mt=8>). Unfortunately, the app is only available for *iOS*. If using an Android-based device (e.g. Samsung Galaxy phone or tablet), **Pix4D Capture** is a good alternative.

The two most important flying parameters required for mapping applications are **image overlap** and **altitude**. Image overlap is required to derive undistorted image mosaics based on photogrammetric analysis (see Section 2.3). The flight altitude will determine the resolution (pixel size) of the imagery. The higher you fly, the coarser the pixel size (less resolution) but the larger spatial extent you will be able to cover per battery. Note that the maximum flying altitude allowed is **120 m** above land

(<https://www.casa.gov.au/aircraft/landing-page/flying-drones-australia>).

It is important to note that if the objective of the project is to map and monitor an area frequently, a set of **permanent markers**, also known as ground control points (GCPs), is preferred (minimum of 3). These markers should be visible from the air (larger than A4 size), clearly defined (e.g. crosses or road intersections) and their XYZ coordinates should be surveyed using precision equipment (**sub-meter precision**) such as Real Time Kinematic GPS or a total station. Note that hand-held GPS has larger errors and is not suitable for establishing precise XYZ coordinates.

Open DJI GS Pro. Tap (1) to create a New Mission.

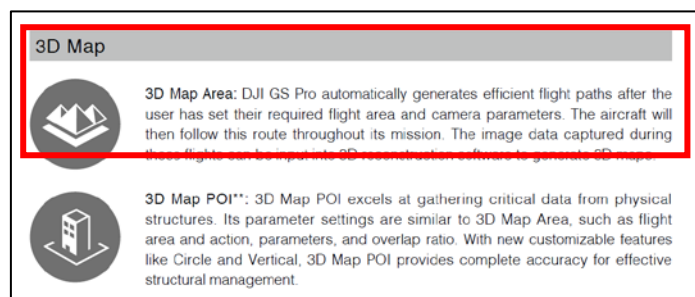


You can select different mission types depending on your project.

Select **3D Map Area**

which will generate efficient flight

paths for capturing images that can be input into 3d reconstructions and maps.



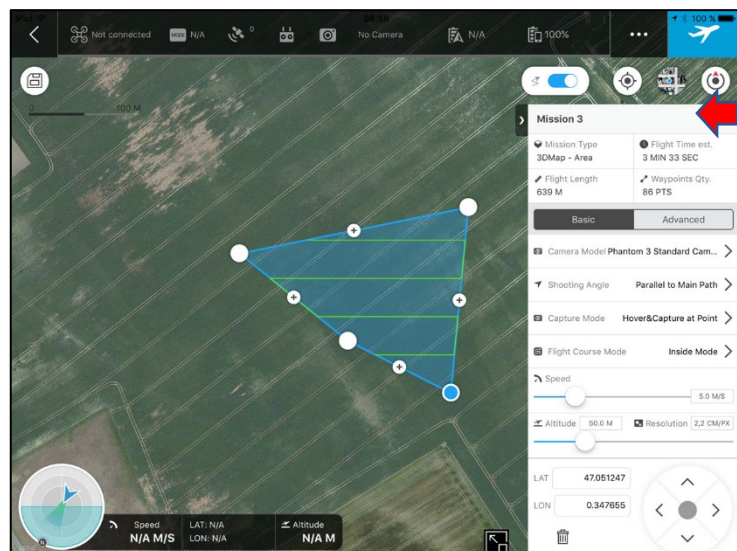


You now need to choose a method to set your study area boundaries. 1) You can tap on the map and drag the points with your finger and/or enter known coordinates, or 2) you can fly the aircraft to the desired position and set the location as a boundary point. 1) is more convenient as you can plan your mission before heading to the field or when you have pre-existing coordinates delimiting your study site (e.g. permanent surveyed markers). 2) is only recommended when you need to precisely establish the boundaries visually and maybe lack internet connection and have no basemap display.

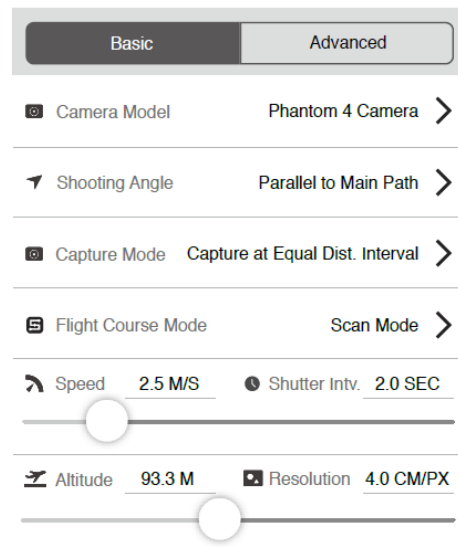


Once you define your boundaries, you can define the settings.

1) Change the mission name (e.g. "Seagrass\_Noosa") and press enter to save.



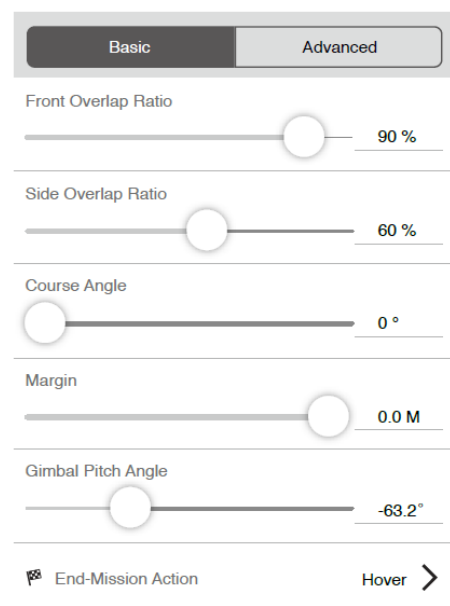
Under **Basic settings**: choose your Camera Model (e.g. Mavic pro or Phantom 4), set Shooting Angle to Parallel to Main Path, set Capture Mode to Capture at Equal Dist. Interval, set Flight Course Mode to Scan Mode. Leave Speed and Shutter Intv. as default. The most important setting here is the **Altitude**. The best compromise between altitude, time and resolution for the mapping extent of seagrass meadows is around **60 or 70 m** which will produce maps at around **2 cm** resolution. The resolution will adjust automatically based on the selected altitude.



Switch to Advanced settings (1). Define the amount of Front and Side Overlap ratios.

The minimum is 60/60% but for a more detailed reconstruction **90% Front and 60% Side** overlap ratios are recommended. Adjust the Course Angle (bearing of flight lines) according to your study area.

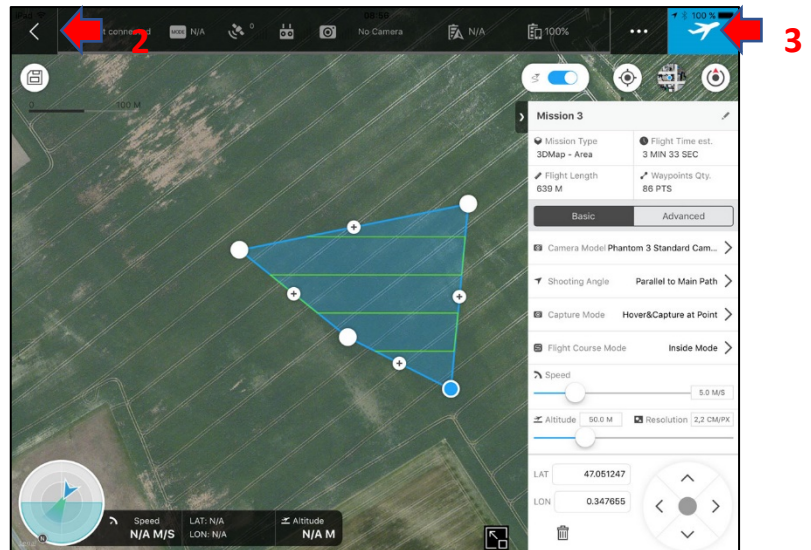
Set the Gimbal Pitch Angle to **-75°** so the camera is pointing slightly at an angle to reduce sun reflection. Set End-Mission Action to **Return to Home** and the return to home altitude (RTH) to **60 m**.



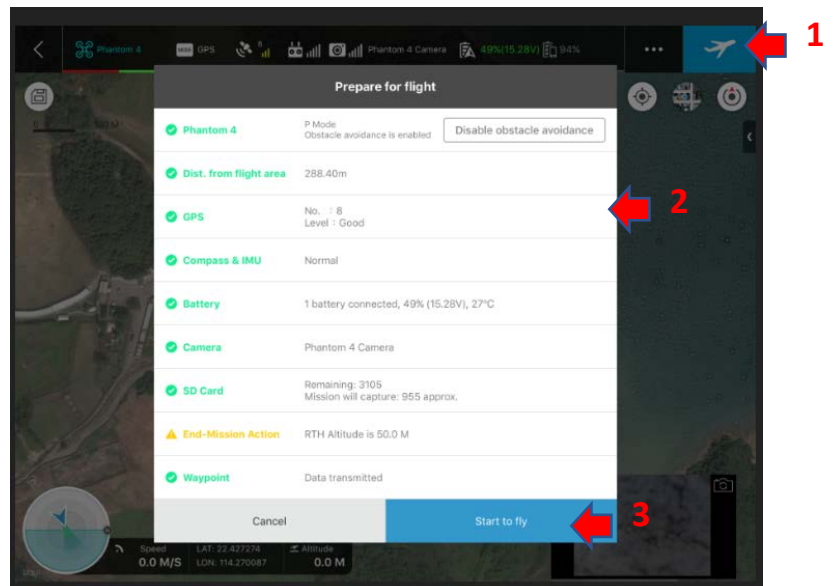
## Save your mission (2).

You can now proceed to fly your mission by pressing (3).

Alternatively, you can close the App and open the mission later.



By pressing (1), several connectivity and flying checks will be performed, including connectivity with drone, distance from flight area, number of locked GPS, compass and IMU, battery, SD card and End-Mission Actions (2).



Once the waypoint data (boundary points) are correctly transmitted, you will be able to fly the mission by pressing the “Start to fly” button (3). The drone will take-off automatically, fly the mission, return to home and land.

**\*Make sure there are no obstacles when taking off or landing, always keep visible line of sight with your drone and constantly monitor the battery levels and functioning of the drone’s camera.**

Once the mission is completed, the photos will be stored in the SD card. Proceed to download and store for subsequent processing.

## Processing imagery

### Creating a dense point cloud from overlapping images

Images from consumer-grade cameras have some level of inherent distortion. Generally, the shorter the focal length (i.e. wide angle), the more the distortion (e.g. fisheye lens). Elevation data can be used to remove image distortion through a process called *orthorectification*. A set of photogrammetric and computer vision algorithms known as Structure-from-Motion (SfM) allows derivation of elevation from *overlapping and scaled images*, which is then used to orthorectify and mosaic imagery. The resulting undistorted mosaic (photomap) can then be used to map the location of features and perform precise measurements such as distances and areas.

Several SfM software packages are available commercially. The most popular ones are Agisoft Photoscan and Pix4D. Both have easy-to-use graphical interfaces and are very efficient at processing large number of photos (100s to 1000s), given the right computing power (e.g. > 16 GB RAM and good GPU card). Freely available SfM software is also available. This guide will be based on the popular free option **VisualSFM** developed by Changchang Wu.

Install VisualSFM by downloading the appropriate operating system version from:

<http://ccwu.me/vsfm/>

For example, select the Windows 64-bit version (1).

Unzip the file to your computer. Unzipping software is available via 7-Zip (<http://www.7-zip.org>).

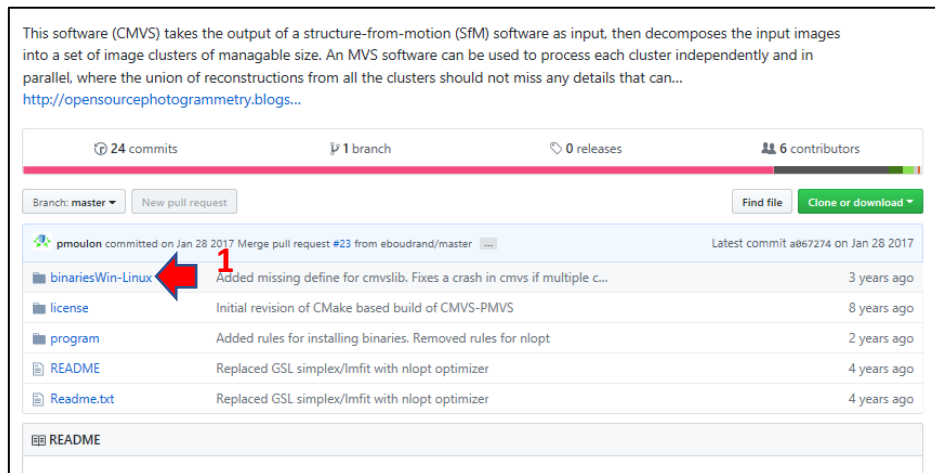
```
Download V0.5.26 (changelog with new feature documentation)
Windows* (64-bit, 32-bit, installation guide), *for nVidia CUDA or CUDA Simulation.
Windows (64-bit, 32-bit, installation guide)
Linux (64-bit, 32-bit, installation guide), see the tutorials for Ubuntu or Fedora.
Mac OSX (64-bit, 32-bit, installation guide), see the installer by Dan Monaghan.

* VisualSFM is free for personal, non-profit or academic use. See README for more details.
* Please cite VisualSFM according to README in your publication.

Documentation (FAQs)
Basic usage, image size, customized matching, controls, parameters, nvm file, demo, ...
Introductory videos(1, 2) and tutorial by Eugene Liscio. French Tutorial by Mathis Fantin.

*The changelist page offers limited documentations for recently added features.
*Post questions and see discussions & tutorials at the Google Group, or email me privately.
```

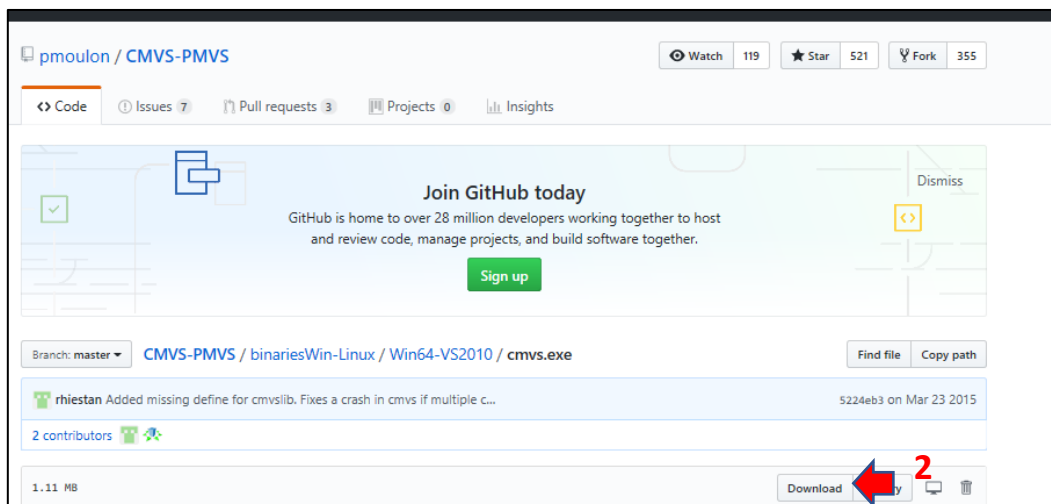
Go to: <https://github.com/pmoulon/CMVS-PMVS> and click the **binariesWin-Linux** folder (1).



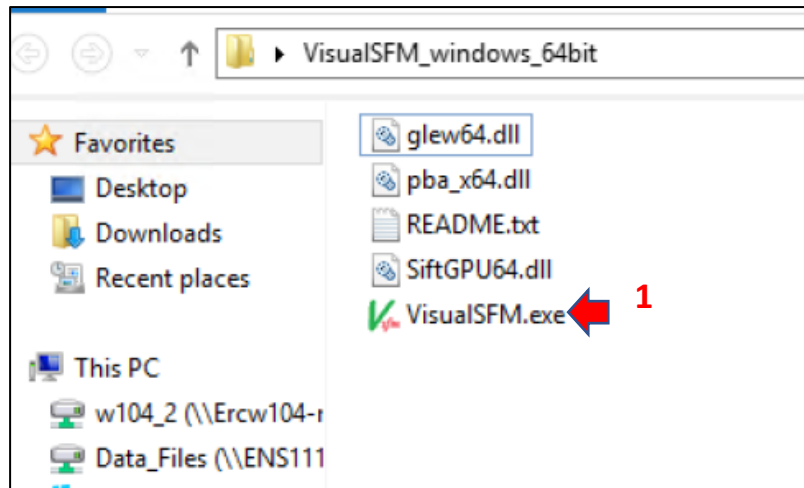
For the Windows 64-bit version, click the **Win64-VS2010** folder and download the following 3 files:

- *cmvs.exe*
- *GenOption.exe*
- *pmvs2.exe*

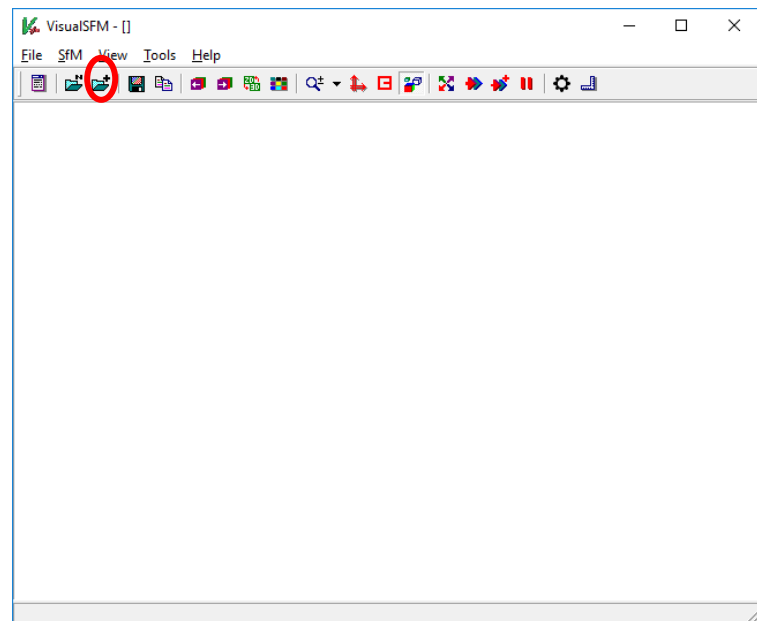
Select each file and click Download (2). Save the files in the unzipped VisualSfM folder (where VisualSfM.exe is located).



Locate the **VisualSFM.exe** file (1) and double-click to launch the software.

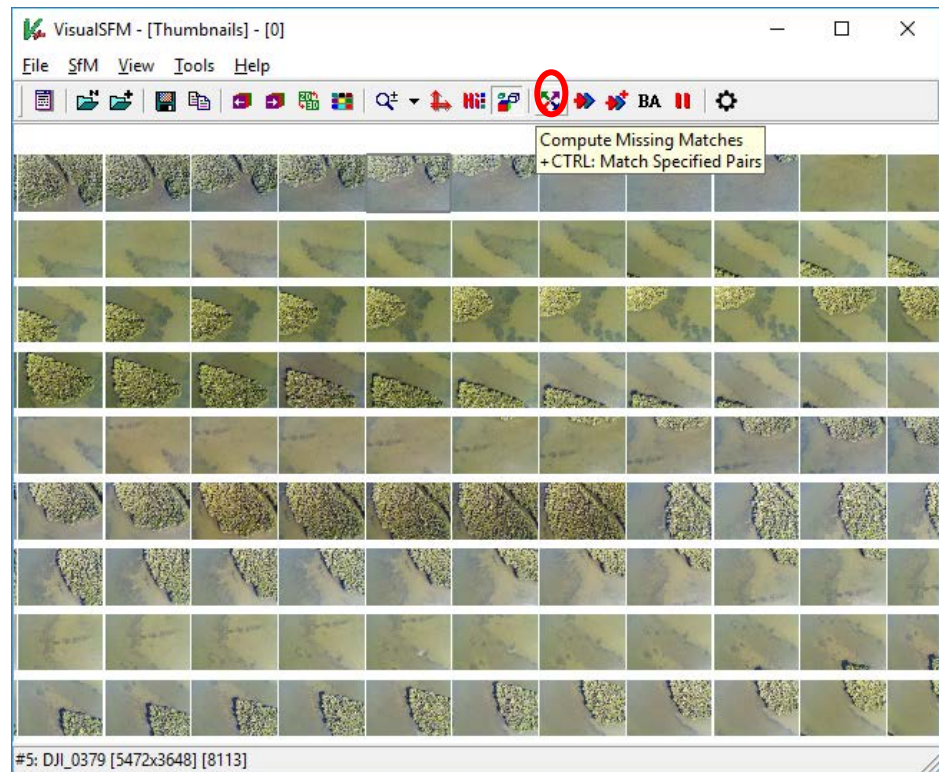


The first step in the process is to upload the images acquired with the drone. Press the **Open Multiple Images** icon, browse to the folder with your images, select them all (hold the shift key) and press open. Depending on the resolution of the photos

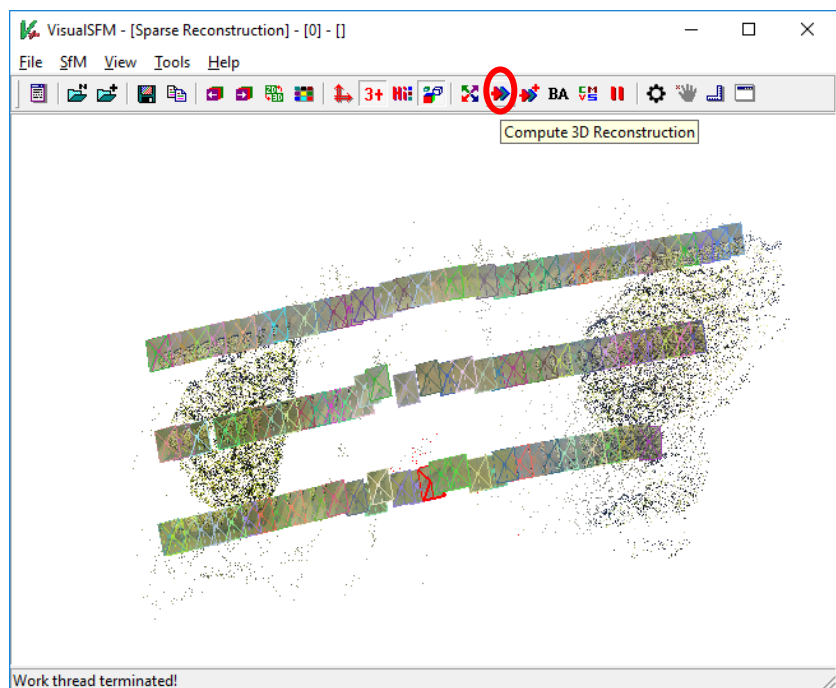


and the computer specifications, this process might last up to **2 minutes for 60-100 images on a high-performance computer (i7, 16 GB RAM, Nvidia GPU card).**

The second step in the SfM workflow is to **Compute Missing Matches**. Press the icon (2). This process can take up to **15 minutes**.



The third step is to **Compute 3D reconstruction**. This will create a sparse point cloud from the overlapping images and assign 3D coordinates to each point (X, Y, Z). This process can take up to **5 minutes**.



The fourth step is to specify the ground control points (GCPs) in order to scale and orient the sparse point cloud. \*GCPs should be placed prior to flying or identified from surveyed permanent markers.

Check each image to see if a GCP was captured in the frame. If there is a GCP in the frame zoom in and **ctrl+left-click** on the centre.

Input the **target ID and XYZ** coordinates, separated by spaces, into the dialogue box that appears. The target ID can be alphanumeric but it must begin with a letter (for



example GCP1). If we zoom in on the target and select the centre as the GCP we can enter “GCP1 153.07503 -26.402922” in the dialogue box. Then click “OK” to set the GCP. By pressing the left or right arrow we can move to another image and repeat the process.

If you hover over a GCP that has already been identified a box shows up around it and you can **ctrl+left-click to edit that GCP**. After you’ve specified enough GCPs in multiple images the Log Window should begin saying “**Transformation estimated successfully!**”.

After you have specified all the GCPs in the images **shift+left-click** on either the GCP-based Transform shortcut or shift+left-click on GCP-based Transform in the SfM menu under **More Functions**. This applies the estimated transformation to the sparse point cloud.

Switch back to the point cloud viewer by selecting N-View 3D Points under the View menu. Your point cloud should now be georeferenced and the GCPs highlighted. The Log Window displays the transformation parameters and the errors associated with the best fit of the transformed GCPs. You can press esc to quit the point selection mode.



The fifth, and last step, is to

### Run Dense reconstruction.

You need to specify a

location for the output files

(e.g.

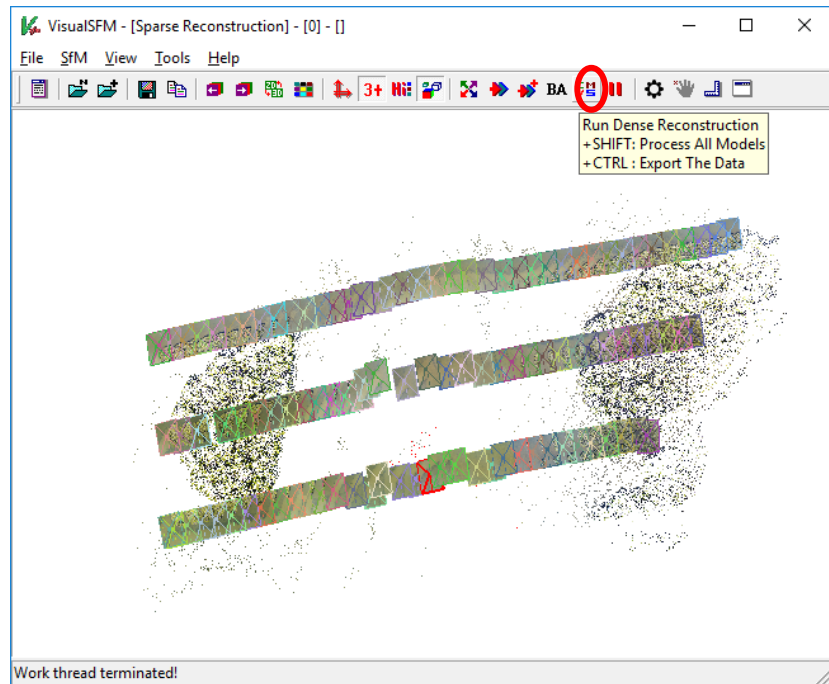
\\Dense\\Seagrass.nvm.smvs).

This process is the longest

and can take up to **30**

**minutes.**

Close VisualSFM.



Creating an orthomosaic from the dense point cloud

You have converted overlapping images to a rectified dense point clouds using VisualSFM.

The second step in the image analysis process consists of taking the dense point cloud and converting it to an orthomosaic image (photomap). We will do this using the free software

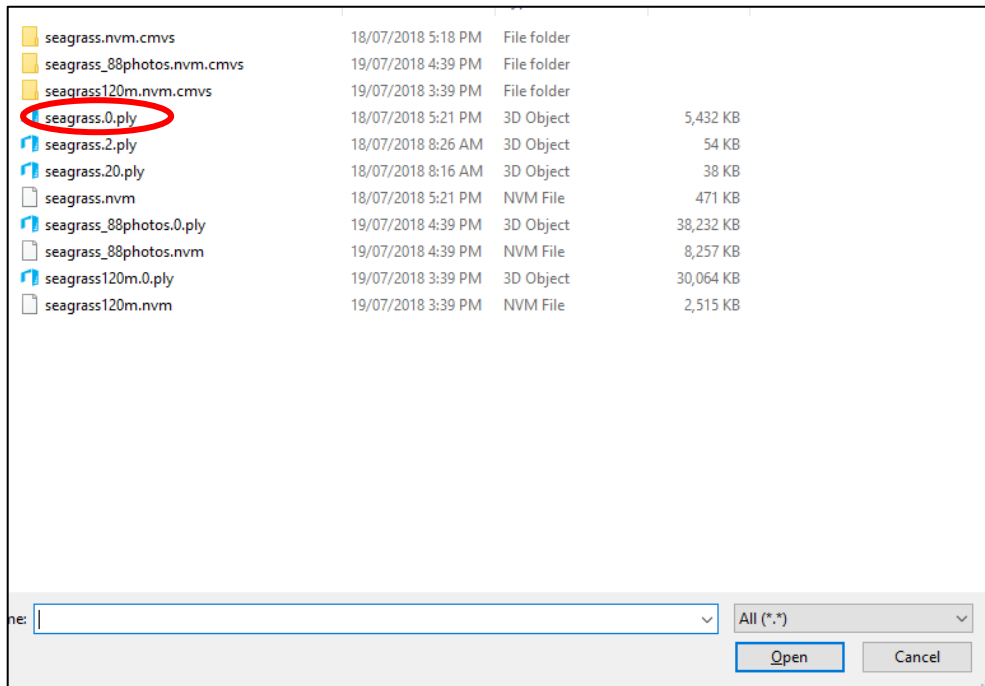
**CloudCompare** developed by Daniel Girardeau-Montaut

Install CloudCompare by going to <https://www.cloudcompare.org/> and selecting Download.

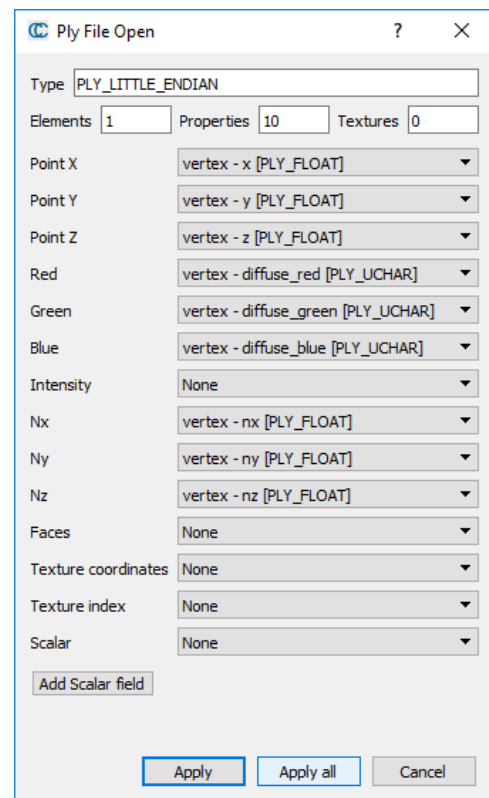
Install the latest stable release for your operating system (1).

Latest stable release (2.9.1 Omnia)			
The 2.9.1 version is mostly the same as the 2.9 + a bug fix concerning DXF export.			
	CloudCompare 2.9.1 installer version	CloudCompare 2.9.1 7z archive version	ccViewer 1.37 7z archive version
Windows 64 bits	Windows 64 bits <b>Stereo</b> (support for Nvidia 3D Vision and Oculus Rift)	7z	7z
Mac OS 64 bits	Thanks to Andy Maloney, MacOS apps are available <a href="#">here</a>		
Linux 64 bits	Now thanks to Alberto Mardegan (and Romain Janvier), there is a "universal" snap package for Linux. On Ubuntu, starting from version 18.04 it's as simple as typing "snap install cloudcompare". On other distributions, you may need to install snap first (please refer to the corresponding documentation if necessary). Snaps are published in 3 channels: "stable", "beta", and "edge". The "stable" and the "beta" channel deliver the latest stable and beta versions of CloudCompare while "edge" delivers nightly builds and may eat your laundry. You can switch at any time between these three channels by launching "sudo snap refresh --channel names" in your terminal.		
Sources	git repository: <a href="https://github.com/cloudcompare/cloudcompare">https://github.com/cloudcompare/cloudcompare</a> (for compilation instructions, refer to the BUILD.md file)		
<a href="https://www.cloudcompare.org">CloudCompare home - cloudcompare.org</a> - EDF R&D - contact			

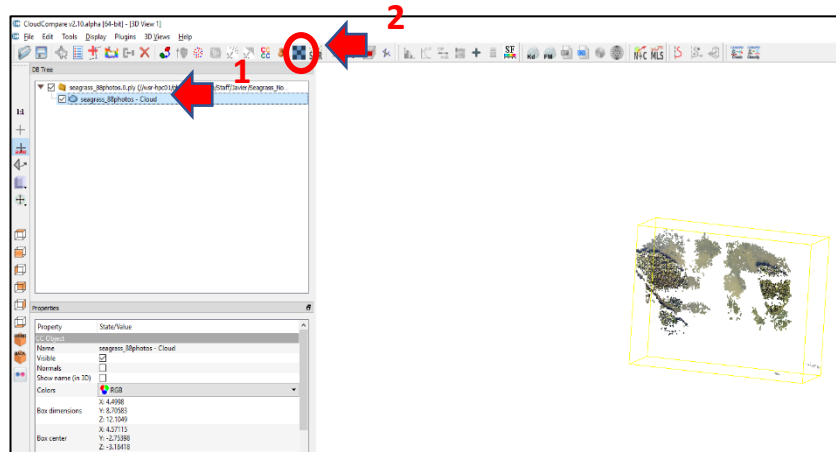
Once installed, launch Cloudcompare.exe, click File/Open and browse to the folder where you saved the dense point cloud generated by VisualSFM (e.g. \Dense\Seagrass.nvm.smvs). Open the PLY mesh file (e.g. seagrass.0.ply) and clicking Open.



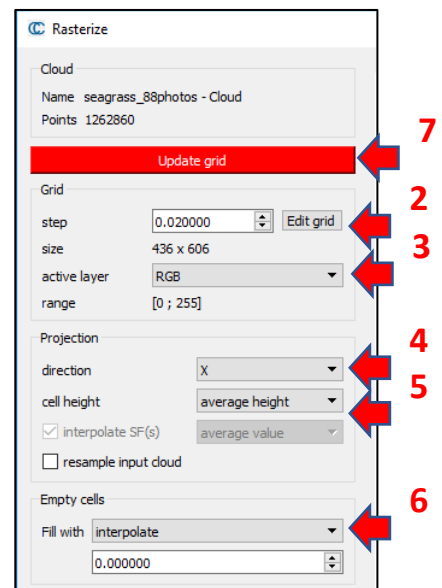
Leave defaults and click **Apply all**



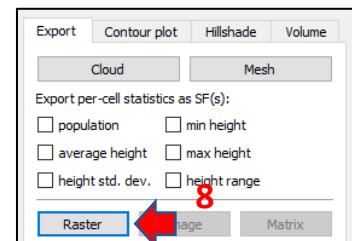
The dense point cloud will open. Select the point cloud by clicking it under the DB Tree (1) and press the **Convert a cloud to 2D raster icon** (2).



Set the step size to the pixel resolution (e.g. **0.02 m**) (2), active layer to **RGB** (3), direction to **X** (4) and cell height to **average height** (5), Fill with interpolate (6) and click Update grid (7).

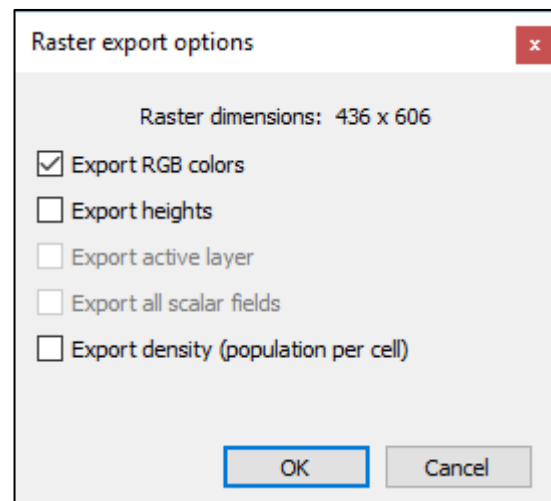


Next, click the Raster button (8)



Finally, in the Raster export options make sure only **Export RGB colors** is checked and click OK. Browse to your working folder and save as a **geotiff file** (e.g. \Noosa\seagrass.tif).

Close Cloudcompare.

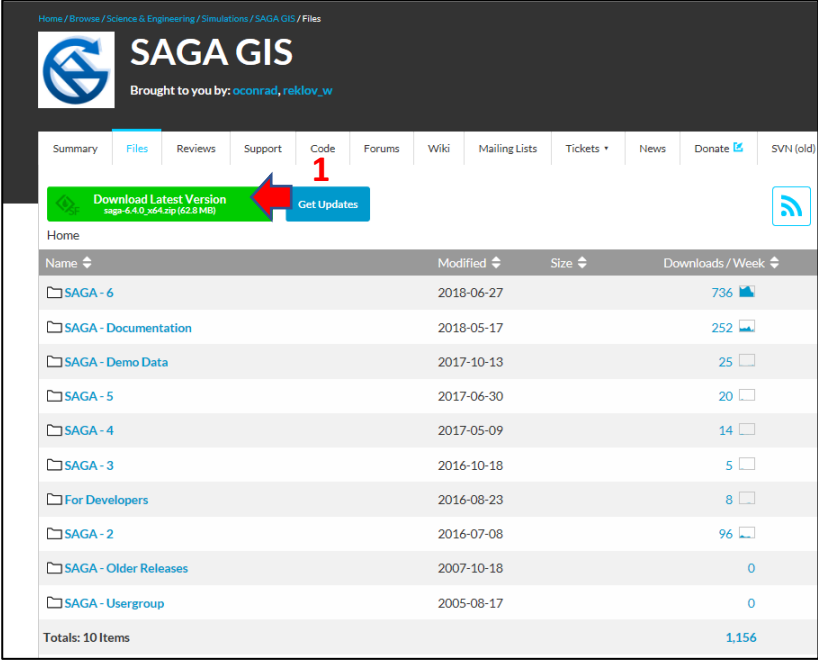


## Classifying and measuring seagrass meadows

The final step in the workflow involves classifying and measuring from the orthomosaic (photomap). This type of analysis is usually undertaken with Geographical Information Systems (GIS) software. The most popular commercial GIS package is ESRI ArcMap. Several free GIS packages exist, with the most popular one being QGIS.

For this tutorial we will be using SAGA GIS (<http://www.saga-gis.org/en/index.html>) developed by J. Böhner and O. Conrad. SAGA is a very light and powerful GIS software.

Install SAGA GIS by going to <https://sourceforge.net/projects/saga-gis/files/> and downloading the latest version (1). Unzip the file to your computer and launch **saga\_gui.exe**



Home / Browse / Science & Engineering / Simulations / SAGA GIS / Files

**SAGA GIS**  
Brought to you by: oconrad, reklov\_w

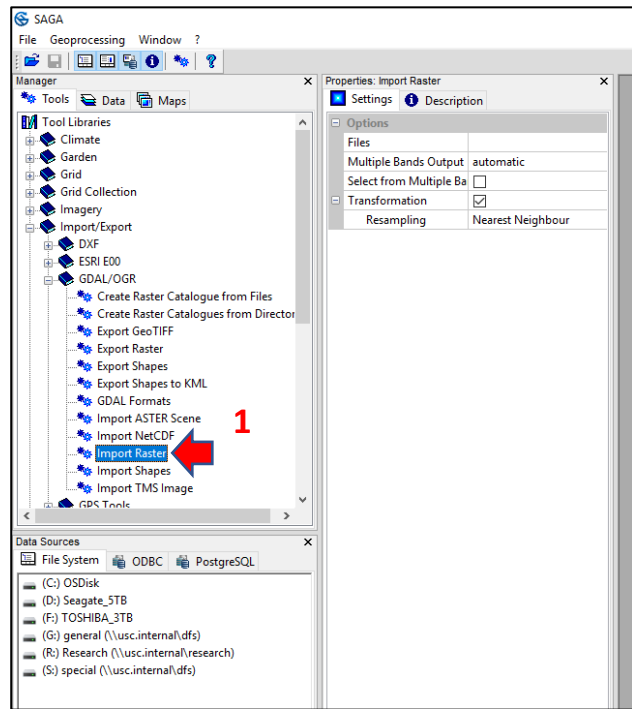
Summary Files Reviews Support Code Forums Wiki Mailing Lists Tickets News Donate SVN (old)

Download Latest Version  
saga-6.4.0\_wsl4.exe (62.9 MB) Get Updates

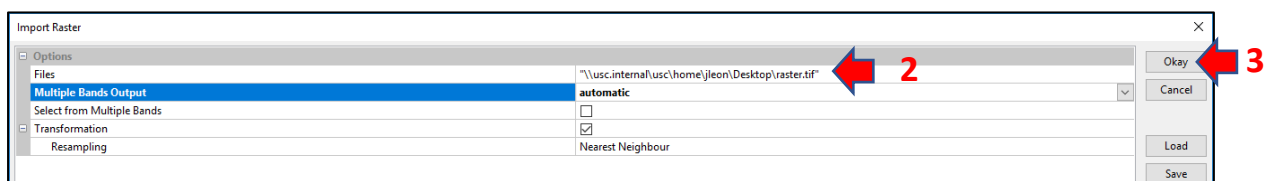
Home

Name	Modified	Size	Downloads / Week
SAGA - 6	2018-06-27		736
SAGA - Documentation	2018-05-17		252
SAGA - Demo Data	2017-10-13		25
SAGA - 5	2017-06-30		20
SAGA - 4	2017-05-09		14
SAGA - 3	2016-10-18		5
For Developers	2016-08-23		8
SAGA - 2	2016-07-08		96
SAGA - Older Releases	2007-10-18		0
SAGA - Usergroup	2005-08-17		0
Totals: 10 Items			1,156

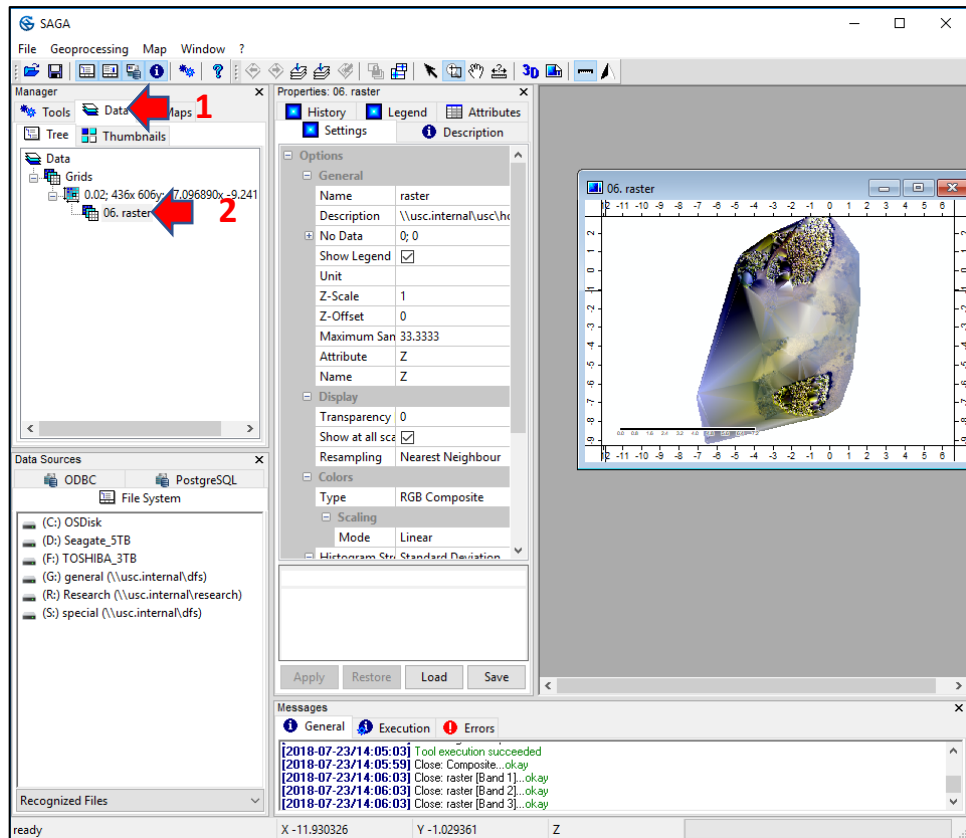
To open the orthomosaic created with CloudCompare, double-click **Tools\Import\Export\GDAL\OGR\Import Raster (1)**.



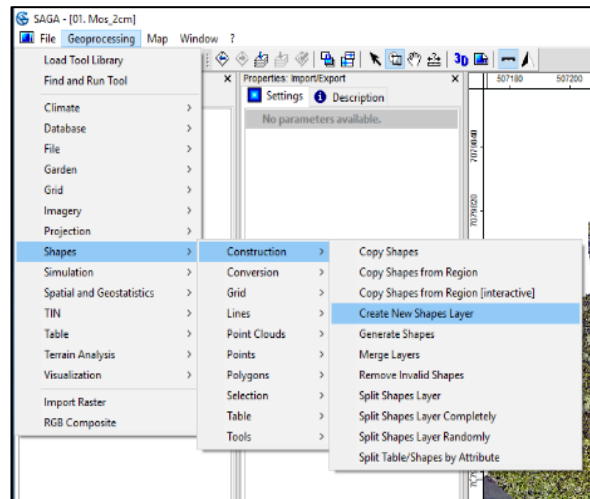
Click and browse to your orthomosaic file (2) and click Okay (3) to open the photmap.



Your image is now loaded. Select the **Data** tab (1) in the manager panel and double click your file to see it (2).

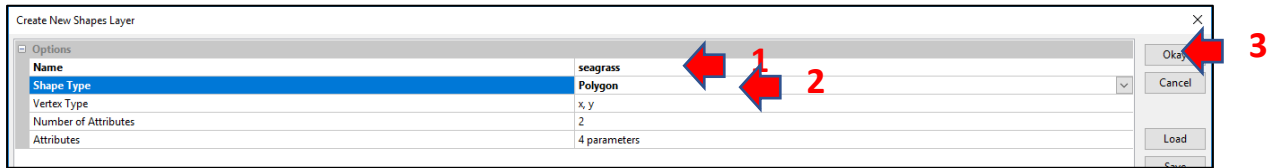


The simplest way of turning your photomap into a **classified map** is by manually digitizing polygons. To manually classify seagrass meadows you need to digitise (draw) a shapefile polygon. Select

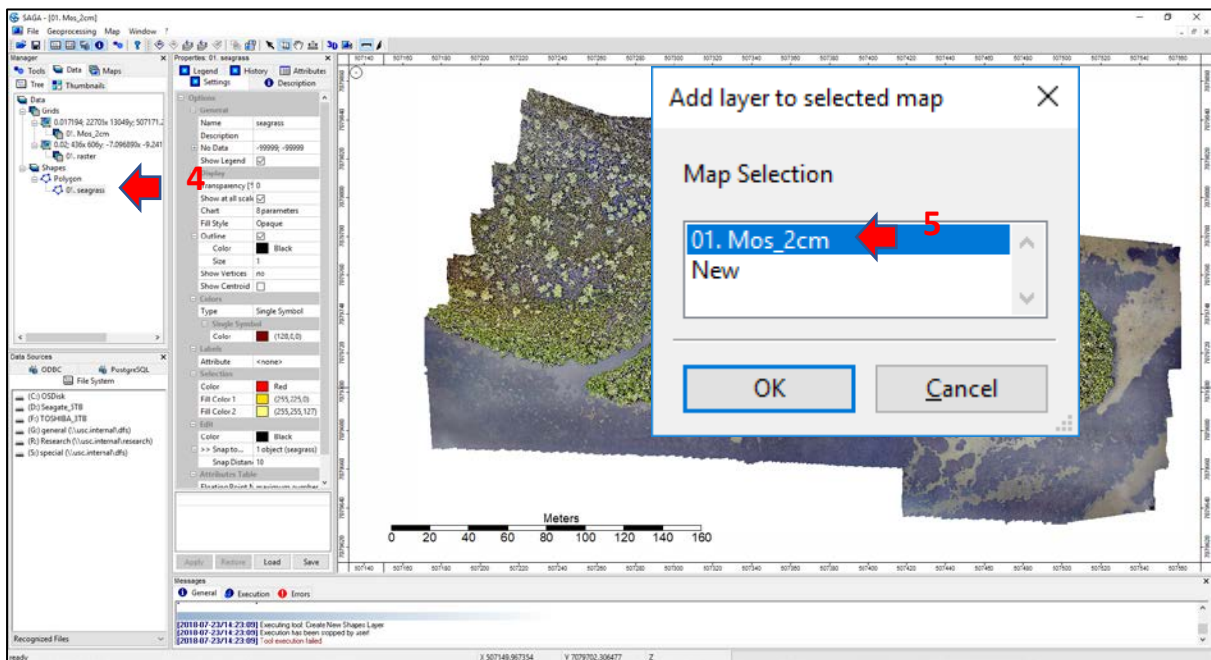


**Tools\Geoprocessing\Shapes\Construction\Create New Shapes Layer**

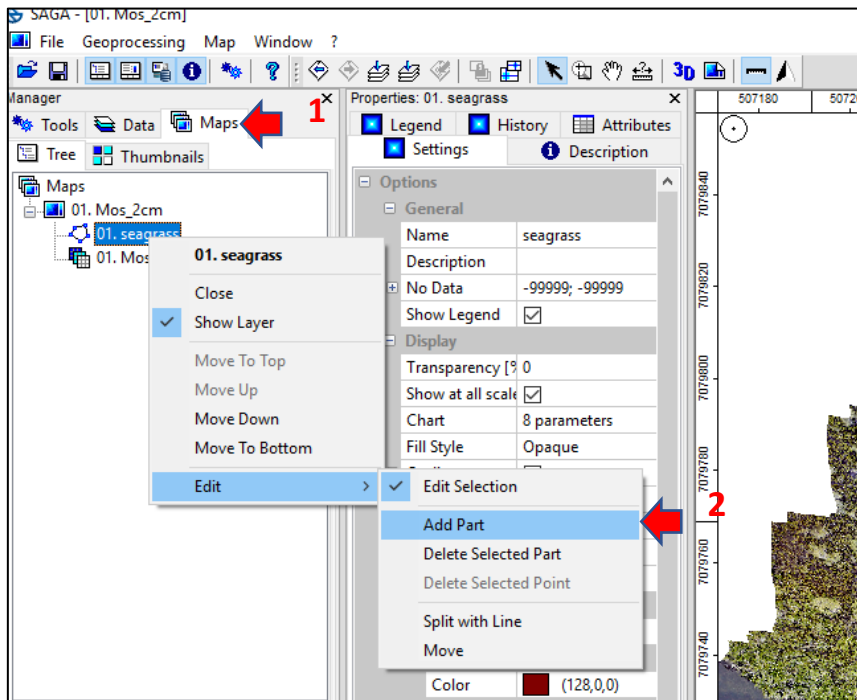
Type a name for your new shapefile (e.g. **seagrass**) (1), select Shape Type **Polygon** (2) and press Okay (3).



Double-click your newly created shapefile (4) and add it to the existing map (5).

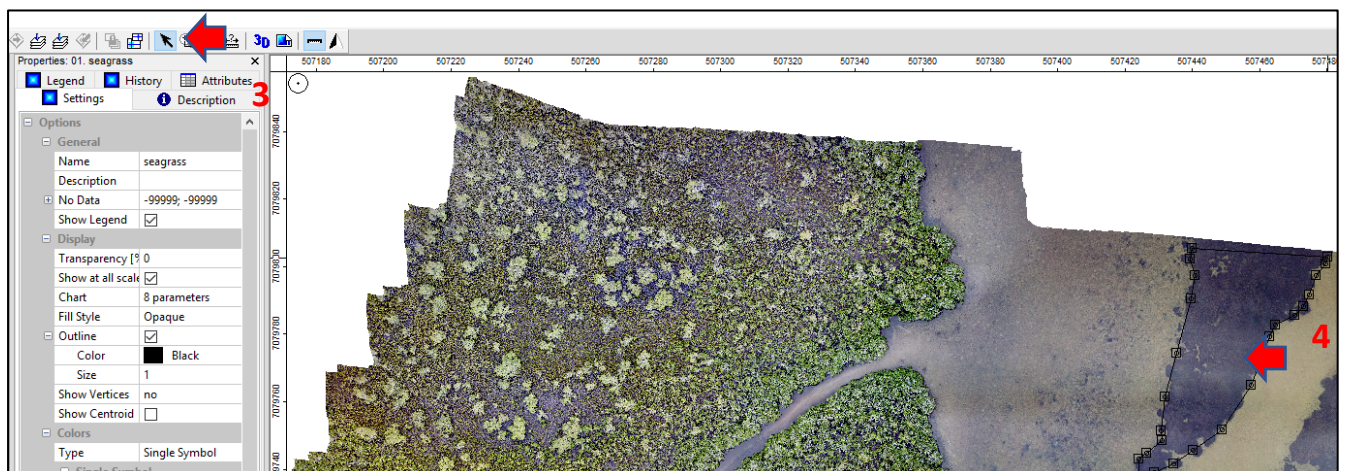


Switch to the Maps tab (1), right-click your shapefile polygon and select Edit\Add Part (2).



Select the Action (arrow) icon (3). The cursor changes to a cross hair with the label *i*. Start digitizing the seagrass meadow by left-clicking. The more clicks, the smoother the polygon (4). Right-click to complete digitizing.

You can remove an existing vertex by moving the cursor over until it changes to a dot circle label. Left-click on the vertex to turn it red and press the right-click to delete selected point.



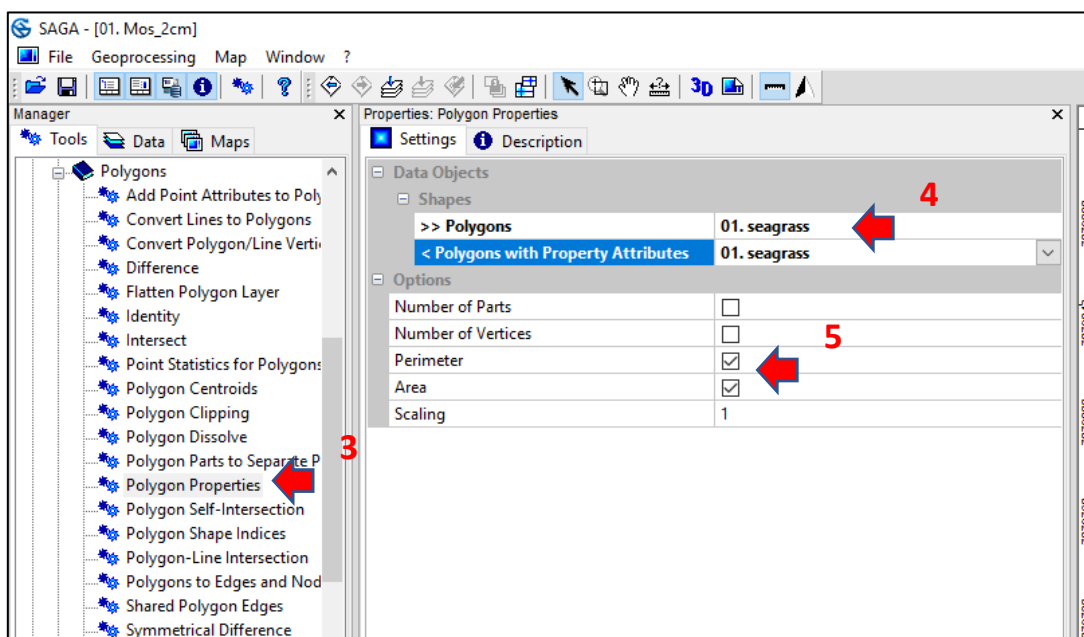


To add another part, right-click anywhere on the map and select Add Part (1).

Once completed, finish digitizing by right-clicking and unchecking Edit Selection and saving the changes (2).



Finally, to calculate the **area** of the newly digitised polygon, go to **Tools\Shapes\Polygons\Polygon Properties** (3). Select your polygon shapefile (e.g. seagrass) under Polygons and Polygons with property Attributes (4) and make sure the Perimeter and Area boxes are checked (5). Click Execute.



To look at the polygon attributes (perimeter and area), go to Data (1), expand the Polygon menu (2), right-click the Polygon with Property Attributes and check show under Attributes (3). You will now see a table with the perimeter and area values (4).

