



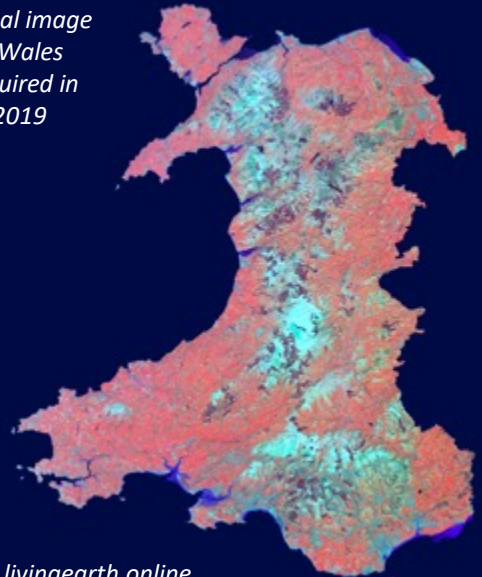
*Suvarna Punalekar, Richard Lucas, Lubomir Tichy,
Sebastien Chognard, Patryk Poslajko and Carole Planque*

WHY A FOREST CANOPY COVER CAMPAIGN?

Satellite Observations

Satellites observing at < 30 m spatial resolution have been continuously passing over Wales since 1985. The Landsat is the best known of these. These archival data acquired provide a unique opportunity to describe the changing state of the Welsh landscape over the past 35 years. The continuation of observations through programs such as the European Space Agency's (ESA) Sentinel-1 and 2 allows monitoring into the future.

ESA Sentinel 2 optical image of Wales acquired in 2019



wales.livingearth.online

Living Wales

Living Wales is a European and Welsh Government-funded research project under the Sêr Cymru programme that is generating detailed maps of land cover for Wales on at least an annual basis. These maps are obtained by simply combining a range of environmental variables retrieved from satellite data, whether archival or recently acquired.



A forest can be described by combining information on lifeform (trees, shrubs), canopy cover and height, leaf type, phenology, number of layers, dominant species, biomass and so on and each of these variables can be retrieved from satellite data.

All map products generated by *Living Wales* are being made available to encourage use across a range of domains and the project is encouraging engagement with people throughout Wales.

Earth Track

The *EarthTrack* mobile app has been developed to support near real time collection and provision of field-based measurements of variables to support evaluation of existing products or development of new satellite-based retrieval algorithms and validation of the derived land cover and change maps. The data are available for download and the resource is continually built as and when new data are added.

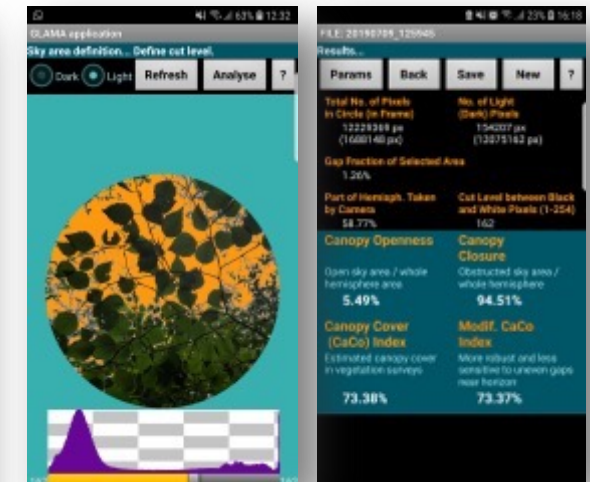


EarthTrack records of land cover, change and environmental variables

earthtrack.aber.ac.uk

Canopy cover

Canopy cover (%) is just one of the environmental variables that *Living Wales* is targeting. The ambition is to obtain > 1000 field measurements across the Wales from mid-August to mid-September. To achieve this, *Living Wales* has established that the GLAMA mobile app is optimal for quantifying canopy cover and that only nine vertically orientated photographs are needed to obtain a robust measure.

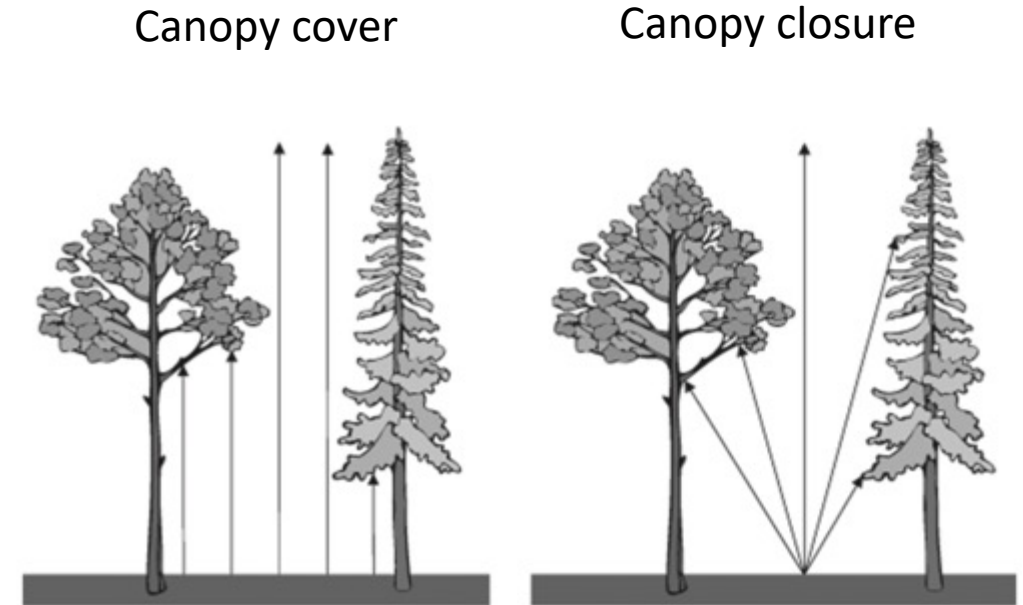


Canopy cover from the GLAMA Mobile App

The following provides an overview of how to install and use GLAMA and submit and retrieve records through *Living Wales*.

CANOPY COVER DEFINITONS

- **Canopy Cover** is defined as the proportion of the ground covered by the vertical projection of tree crowns.
- At any given point on the ground, canopy cover can be recorded as 0 or 1 meaning absence or presence of the canopy above this point.
- Canopy is independent of the height and number of layers.
- Canopy cover is easily confused with the **canopy closure**, which is the proportion of sky hemisphere obscured by vegetation when viewed from a single point.
- Unlike canopy cover, canopy closure is sensitive to vegetation height and the number and density of layers.



Canopy cover can be retrieved from data acquired by LIDAR, optical and radar sensors, whether supported by airborne or satellite platforms.

WHY MEASURE CANOPY COVER

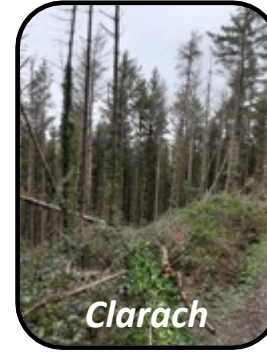
- Canopy cover is an environmental variable relevant to vegetation and a key descriptor of forests.
- Canopy cover supports decisions on forest and woodland management and conservation and is a key parameter in land surface process modelling.
- It can also be useful for characterizing habitat connectivity and suitability and monitoring tree diseases (e.g. ash dieback).

Monitoring progress of plantation projects



Areas under different stages of continuous cover forestry

Monitoring Disturbances



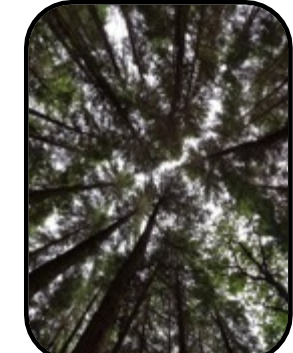
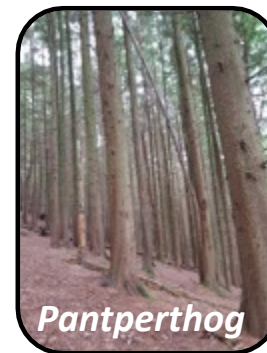
Windthrow

Monitoring seasonal changes

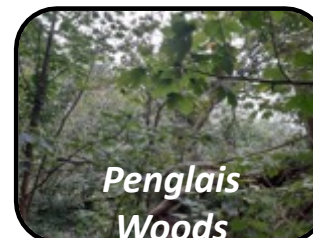


Leaf off (winter) and leaf on (summer)

Understanding impacts of forest structure on biodiversity and function



Needle-Leaved Evergreen plantation



Mixed Broadleaf Deciduous Forest

CANOPY COVER MEASUREMENT PROTOCOL

- Traditionally, canopy cover has been estimated from instruments (hemispherical photographs, LAI 2000) that are costly, time consuming to use and require expert scientific skills and knowledge.
- However, several mobile apps are now available to estimate tree canopy cover from vertically upward looking pictures, with examples being Canopy Cover Free, Canopeo, the Canopy Cover app and GLAMA.
- Based on literature survey and testing (through comparison with the Cajanus tube survey method), the GLAMA app is considered to be the most robust for estimating canopy cover for forests in Wales.
- This manual provides instructions on how to concurrently use GLAMA (and the Level Camera App) and EarthTrack Wales app for recording forest canopy cover and land cover information for any site in Wales.
- The resulting canopy cover data are made freely available on the EarthTrack site associated with Living Wales (earthtrack.aber.ac.uk)

CANOPY COVER

MEASUREMENT PROTOCOL

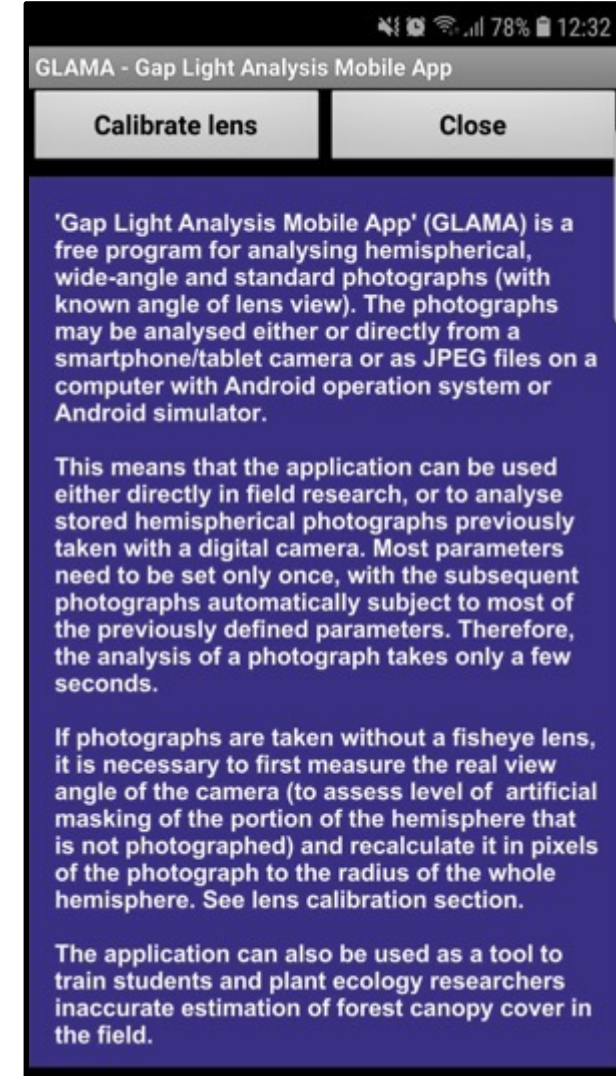
STEP 1: Install GLAMA on the phone

- Install GLAMA app from the Google Play store. (some key words like 'canopy' may help to find the right app).



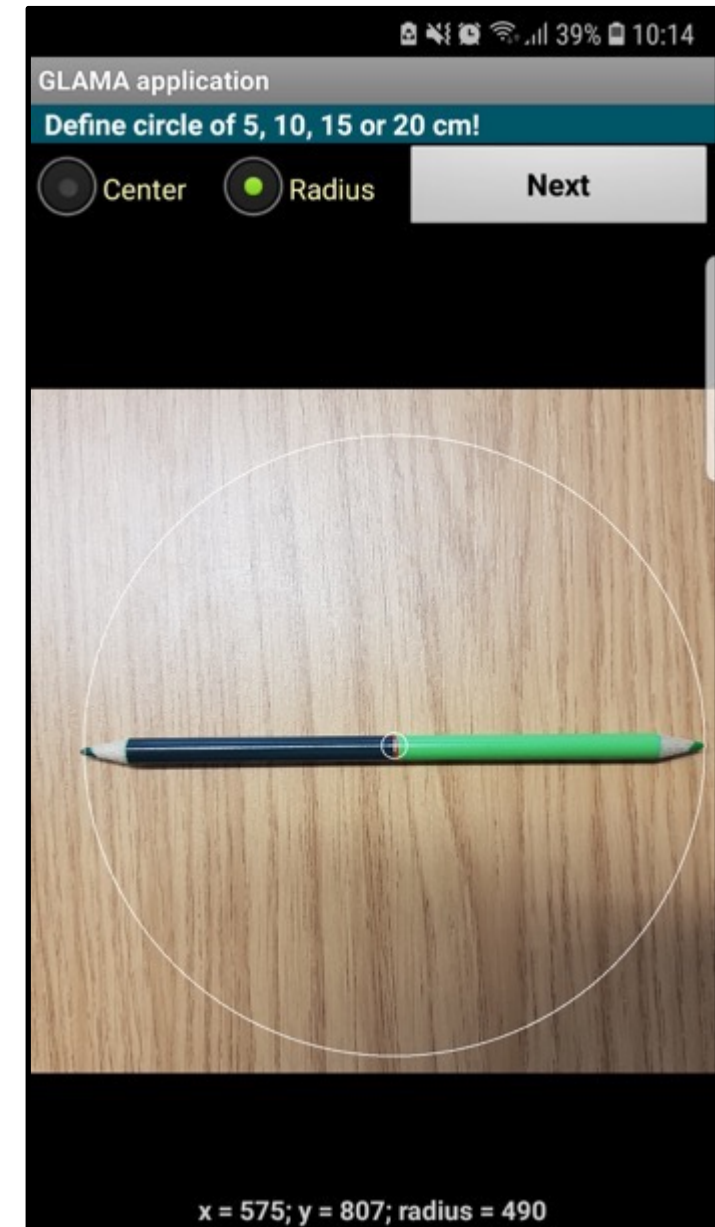
STEP 2: Calibrate GLAMA

- **Open GLAMA.**
- Click on the **setting** Sign on the app display.
- Click on the **Calibrate Lens** button.



STEP 2: CALIBRATE GLAMA

- Take picture of a stick or any linear object like pencil of known length (approx. between 20 to 30 cm). Make sure you have marked the midpoint of the stick.
- Make sure you are using the main camera of your mobile. **Do not use the 'selfie' mode.**
- Make sure that the midpoint is approx. in the center of the photograph.
- Note down the distance between camera lens and the length of object (measure with a ruler).
- Once you take the picture, click on the 'Center' button at the top of the GLAMA page and click on the midpoint of the object in the picture to align the cross-hair with it.
- Then click on the 'Radius' button and align the white circle on the screen such that it passes through the two tips of the object in the picture.
- Click on the NEXT button.



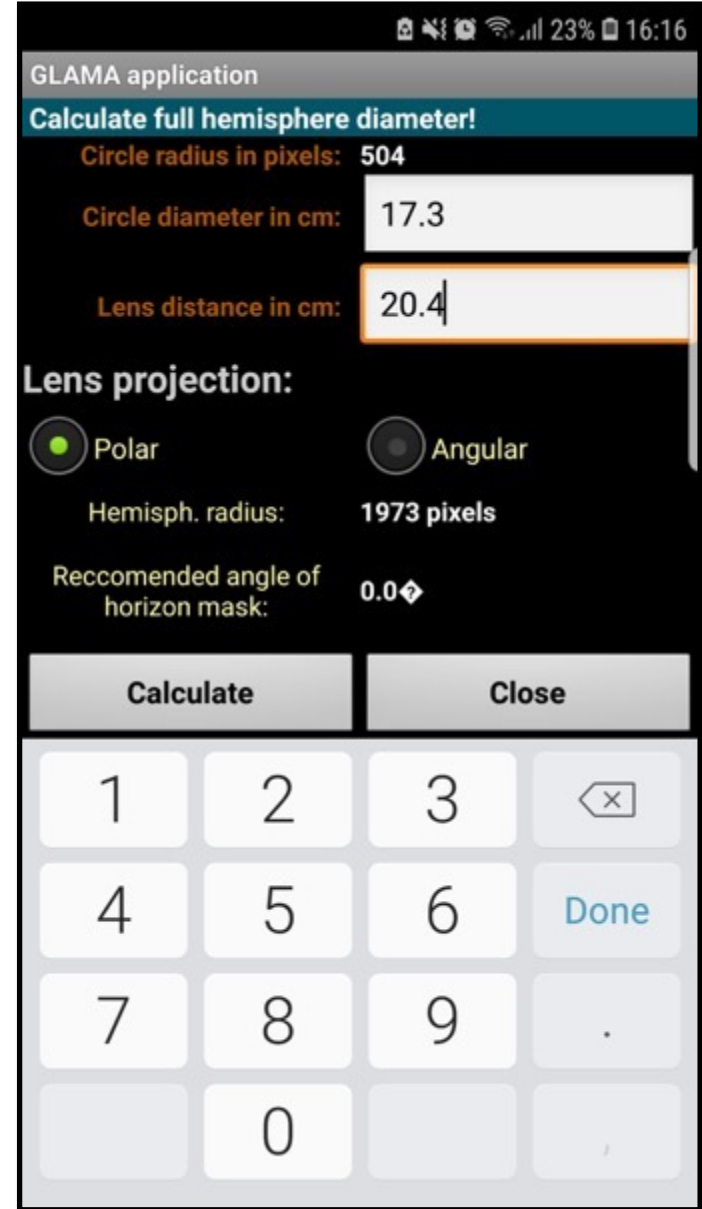
STEP 2: CALIBRATE GLAMA

- Fill in 'Circle diameter in cm' and 'Lens distance in cm' with the values you measured previously.
- Set Lens projection to 'Polar'
- Click on the 'Calculate' button.
- Note down the 'Hemispherical radius' value.

Note: For the calibration step you can also use a circular object such as Plate with its center marked.

The hemispherical radius is important input for the GLAMA analysis.

Please note down the value OR take a screenshot of this page for the record.



The screenshot shows the GLAMA application interface on a mobile device. The status bar at the top indicates 23% battery and 16:16. The app title is "GLAMA application". The main heading is "Calculate full hemisphere diameter!". Below this, there are three input fields: "Circle radius in pixels: 504", "Circle diameter in cm: 17.3", and "Lens distance in cm: 20.4". The "Lens projection:" section has two radio buttons: "Polar" (selected) and "Angular". Below this, it shows "Hemisp. radius: 1973 pixels" and "Recommened angle of horizon mask: 0.0". At the bottom, there are two buttons: "Calculate" and "Close". A numeric keypad is visible at the bottom of the screen, with a "Done" button.

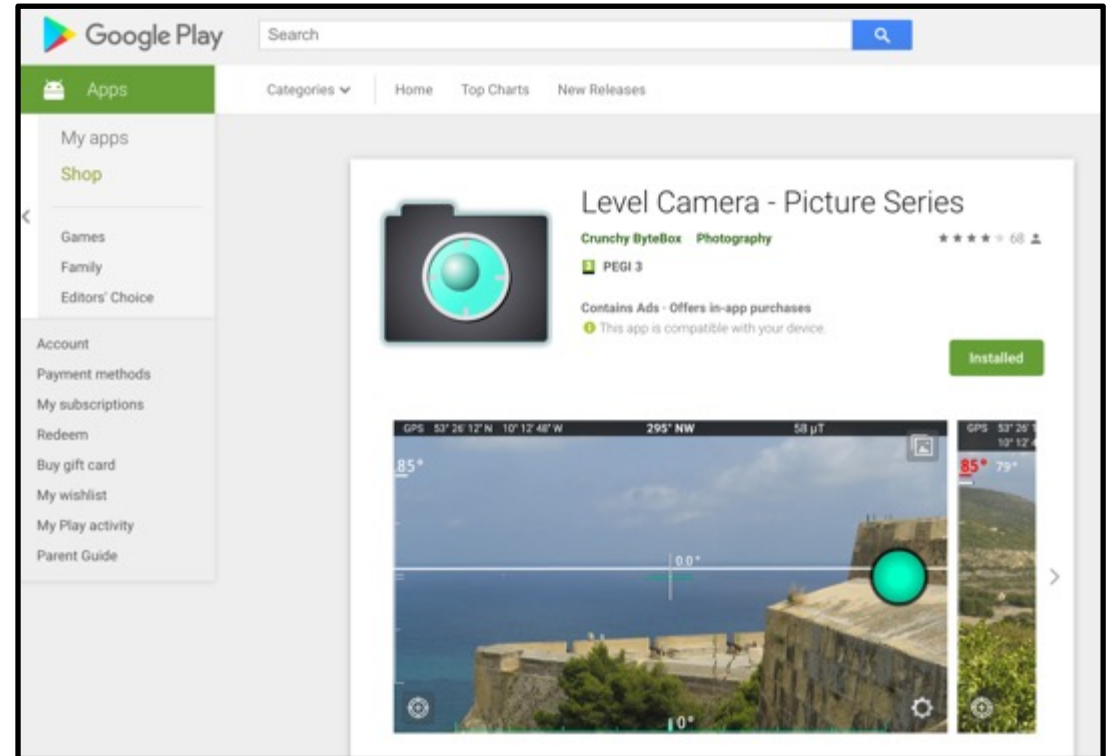
STEP 3: INSTALL THE 'Level camera app'

GLAMA can calculate canopy cover from the pictures instantly taken from the camera OR you can upload an already captured photograph.

Use the **'Level Camera'** app to take vertically upward looking pictures to ensure proper horizontal leveling of the camera.

'Level Camera' is available from the Google Play Store.

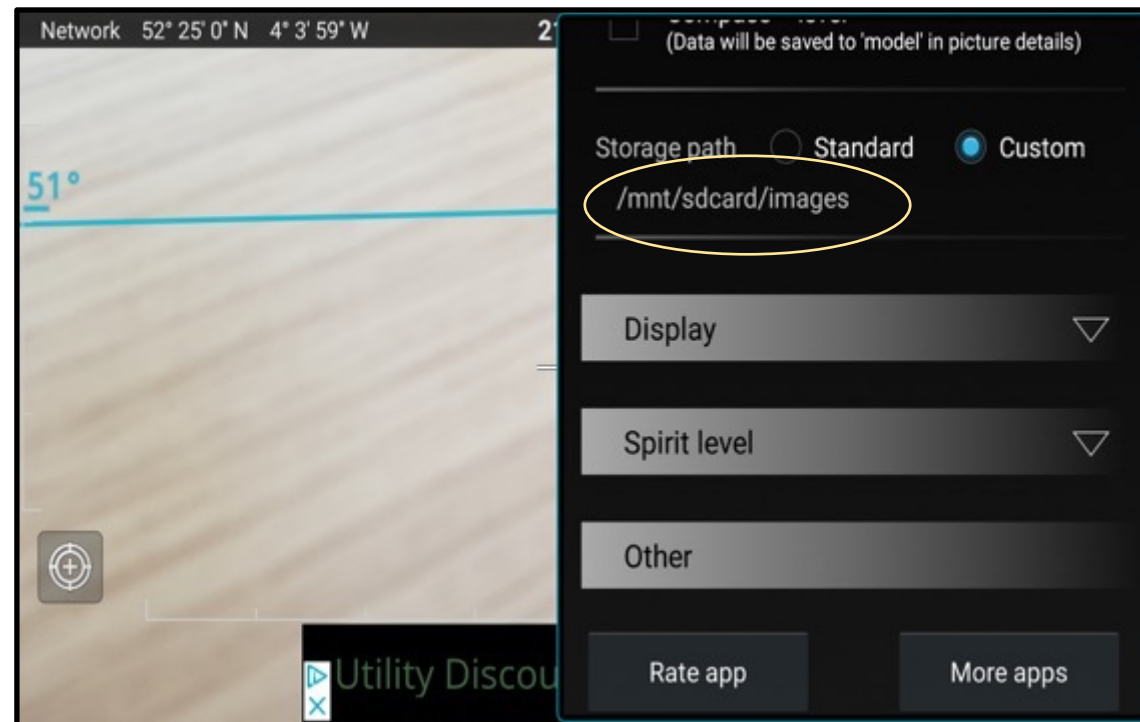
Click on install, open and agree to the terms.



STEP 4: SET UP THE FOLDER TO RECEIVE THE PHOTOGRAPHS

In order to make sure that pictures captured by the Level Camera app are directed to a folder that GLAMA can access, follow the steps below **just after you install Level Camera.**

- Open the Level Camera app
- Click on the 'setting wheel' button, which you will see on the main screen of the app.
- Scroll down to the Storage Path options.
- Click on the 'Custom' button.
- A warning message may pop up. Click on the okay button.
- Navigate to the 'images' folder and click okay.
- Scroll to the top and select Close.



(The file path may appear slightly different on different Phones. Always make sure you choose the path based on the folder that GLAMA can access. Sometimes you may have to click a random picture using GLAMA app to create this folder and then access through the LevelCamera.)

STEP 5: INSTALL THE LEVEL CAMERA APP

To take pictures using 'Level Camera', start the application and orient your mobile such that the colored dot is perfectly encircled by the hollow circle in the middle of the screen.

Click on the Picture button to capture the image of the canopy.

Turn the volume of your phone to maximum.

The app generally should make some a sound or visual notification (e.g. the outer circle stops spinning), when the image has been successfully captured.

The image should be saved to the 'MyFile/Images/images' folder on your phone.

ALWAYS use your Main Camera to take pictures and not the Selfie Mode Camera.

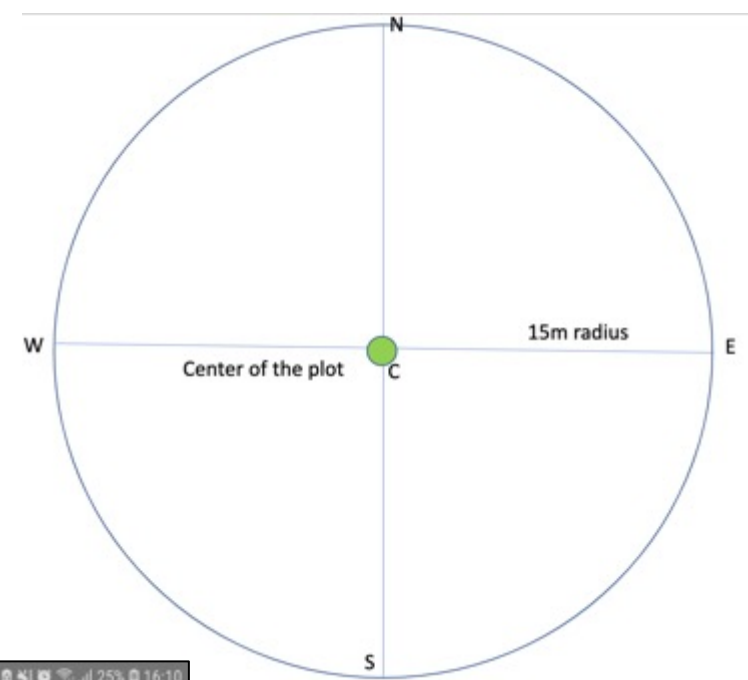


Note: Some old mobile phones may not have access to the Level camera or similar apps. In that case, open the GLAMA app and take pictures using 'From Camera' option. Try to keep your camera levelled while looking upwards. In this case, you can analyze photos (Step 7) straight away, or you can close the GLAMA app and access photos later for analysis using the 'From file' option.

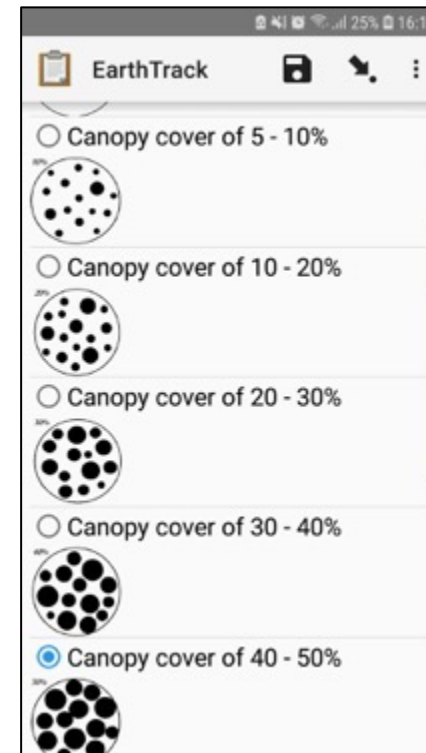
STEP 5: RECORDING A PLOT ON THE EARTHTRACK APP

Out in the field...

- Locate the center of your circular plot. This plot should be of 15 m radius (30 m diameter) in size.
- Using the EarthTrack app (download from earthtrack.aber.ac.uk), record the center point and the land cover characteristics of a circular area.
- You will be asked to provide one visual estimate of canopy cover.
- When you have completed filling the form, save and exit from EarthTrack (remember to submit this when you are back in wifi access).
- **Make sure you note down the plot ID (this should be the same as you entered in Earthtrack).**



Establishing a circular plot of 15 m radius

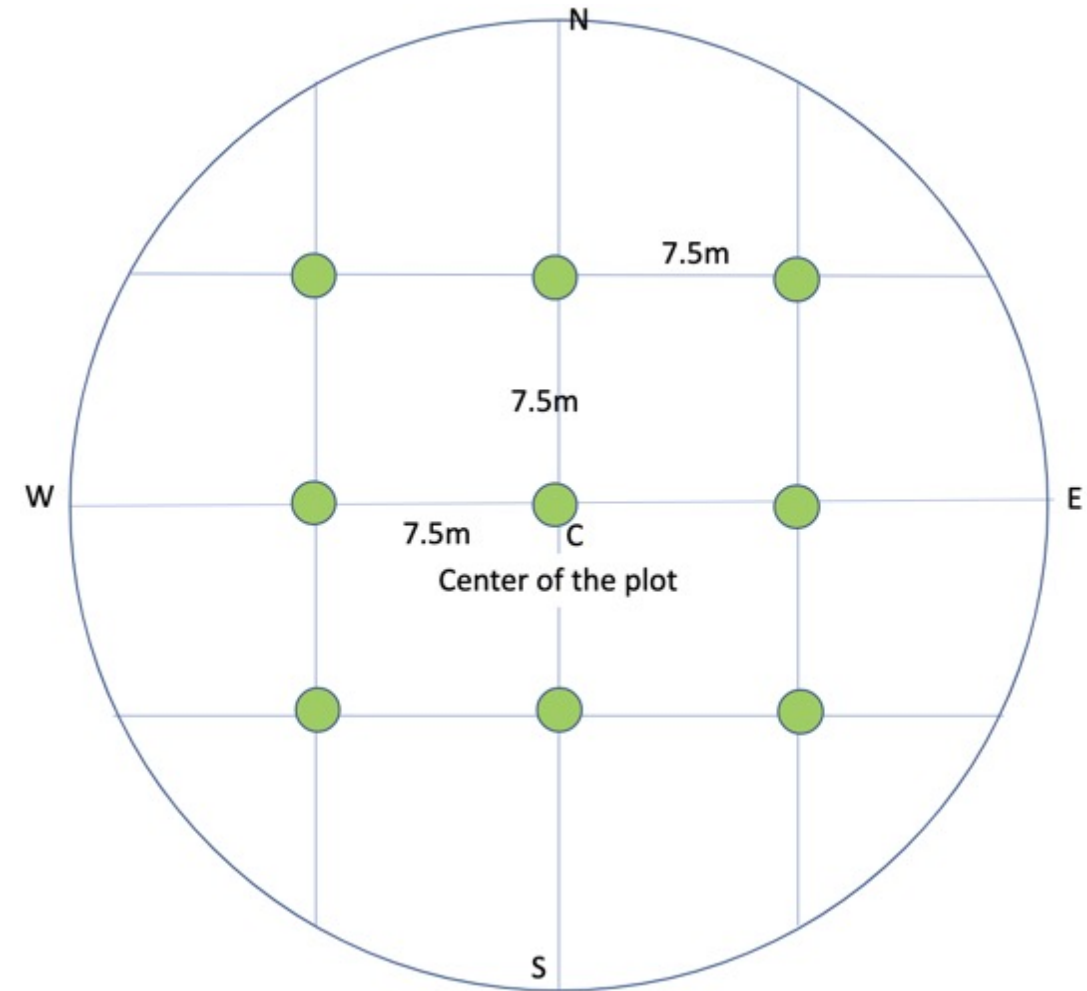


Visual estimate of the top layer Canopy cover in the EarthTrack app

STEP 6: TAKING NINE CANOPY PICTURES WITHIN THE CIRCULAR PLOT

The following protocol has been found to be suitable for obtaining reasonably accurate estimate of canopy cover for a circular plot of 15 m radius.

- Take the first vertically upward picture, using 'Level Camera' at the center of your plot.
- Make sure your camera position is about 2 m above ground and always use the main camera.
- Then take 8 more photos at the locations shown in the picture, using the level camera. You should nine pictures for a plot.
- The distance can be based on your steps. (e.g., 15-18 small steps can cover 7.5 m)
- **Make sure you note down the plot ID (as you entered into Earthtrack) as well as the start and end time when you took nine photos.**



STEP 7: ANALYSING THE PHOTOS USING GLAMA

You can analyze the pictures you have taken instantly in the field or when you come back from the field.

If you are analyzing photos after you have returned from the site, you can trace back to photos of the respective plot based on the time stamp in the title. This information is generally included in the file name of the picture.

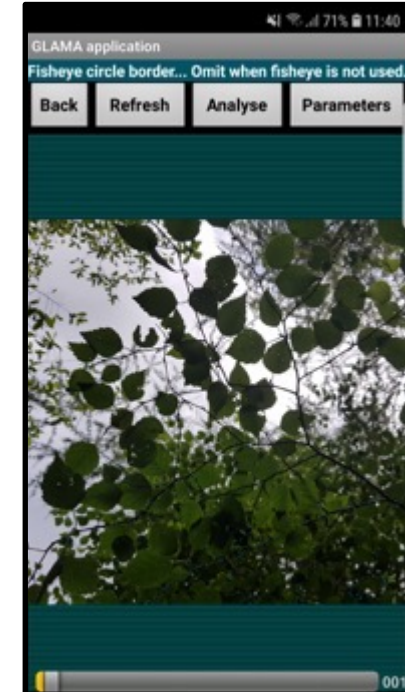
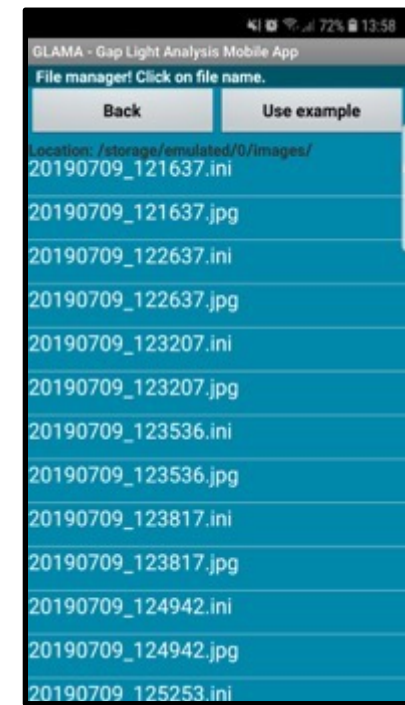
To do the analysis use '**from file**' option. As long as you have performed STEP 4 correctly, you will see a list of all the pictures using the 'from file' option.

In case you don't have 'LevelCamera' app, use '**From camera**' option and click pictures directly from GLAMA, making sure you are maintaining horizontal alignment.



STEP 7: ANALYSING THE PHOTOS USING GLAMA

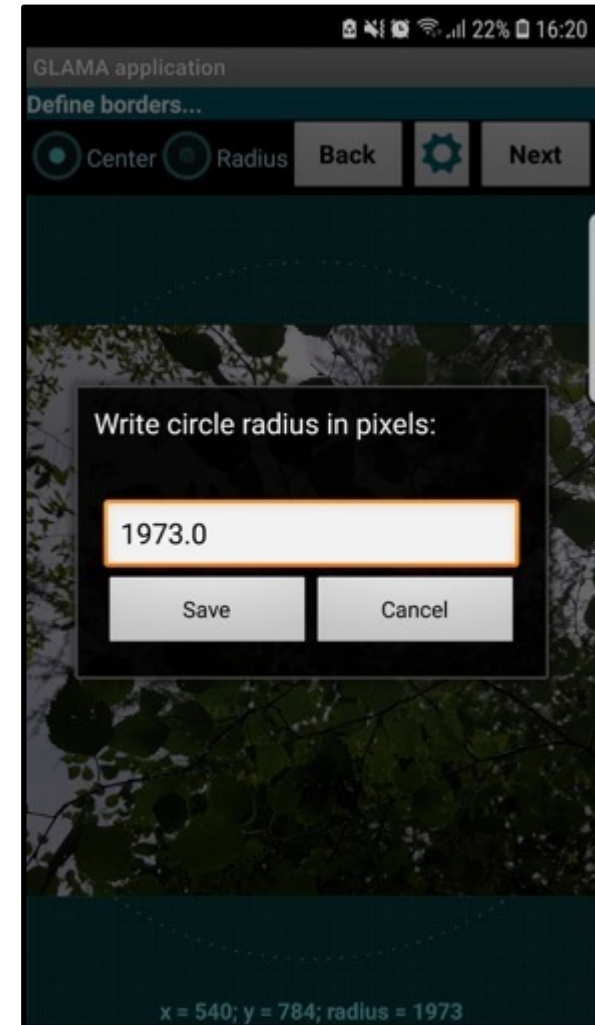
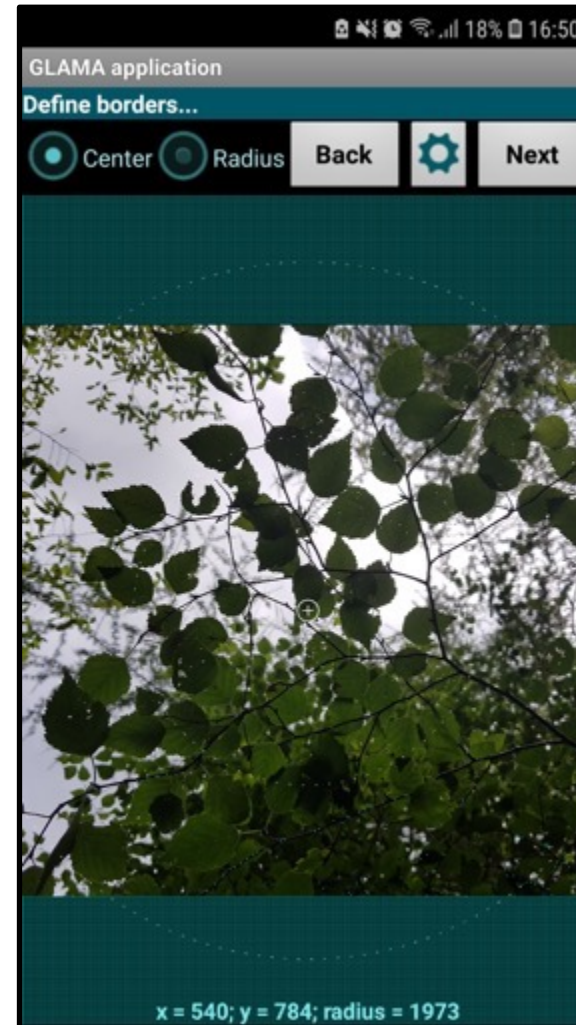
- Open the GLAMA app.
- Click on the 'From file' option.
- Select the photograph you want to analyze.
(note the date and time stamp in the file name to keep track of pictures you are analyzing).
- Clicking on the picture name will load it in GLAMA.
- Click on the **NEXT** button on the 'Rotate and transpose image' page.
- Click on the **Parameters** on the 'Fisheye circle border' page.
This will open the 'Define borders' page.



STEP 7: ANALYSING THE PHOTOS USING GLAMA

On the 'Define borders' Page:

- Check the 'Radius' option on.
- Then Click on the setting wheel button.
- A window will pop-up. Asking for 'circle radius in pixels'.
- **Fill in the value that you have got in the calibration step (Step 2) and not 1973.**
- Click on the 'Save' button.
- Then click on the 'NEXT' button

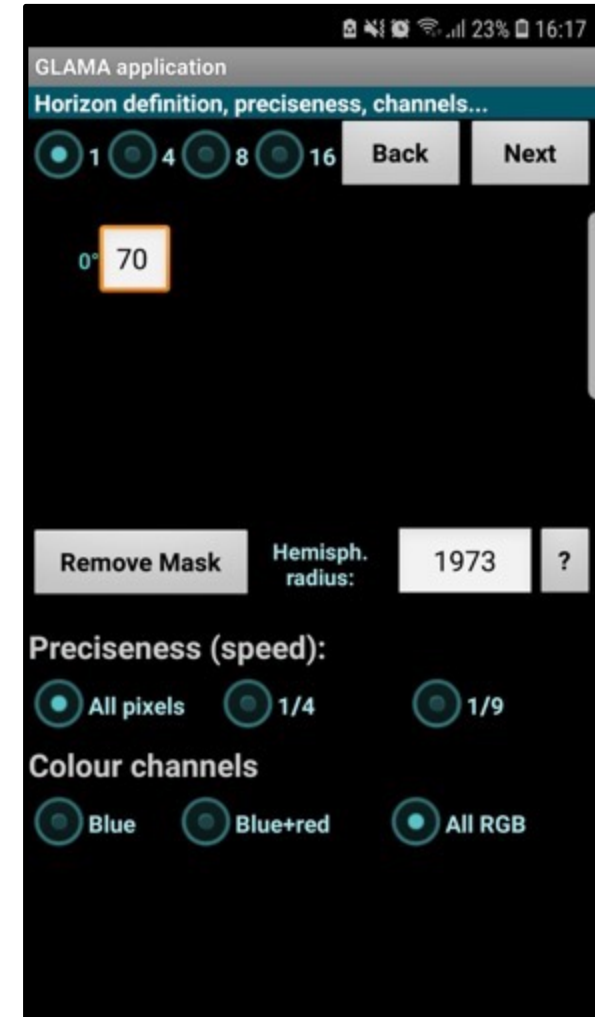


STEP 7: ANALYSING THE PHOTOS USING GLAMA

- Make sure you have checked on the 'Polar' button on the Lens projection Page. Then click NEXT.

On the 'Horizon definition, preciseness, channels' page:

- Check a radio button in front of '1'
- Then set angular mask value to 70° (beside 0°)
- Make sure the value in 'Hemisph. radius.' is exactly what you filled in for 'Radius in pixels' on the 'Define Borders' page.
- In 'Preciseness', click on 'All Pixels'
- In 'Colour channels', click on 'All RGB'
- Finally click on the 'NEXT' button



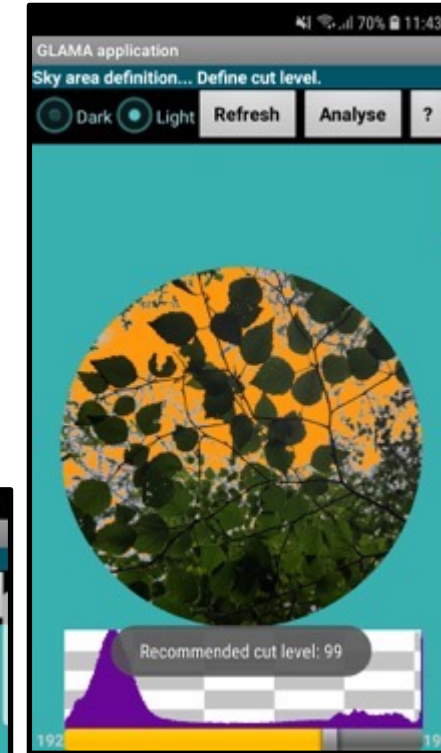
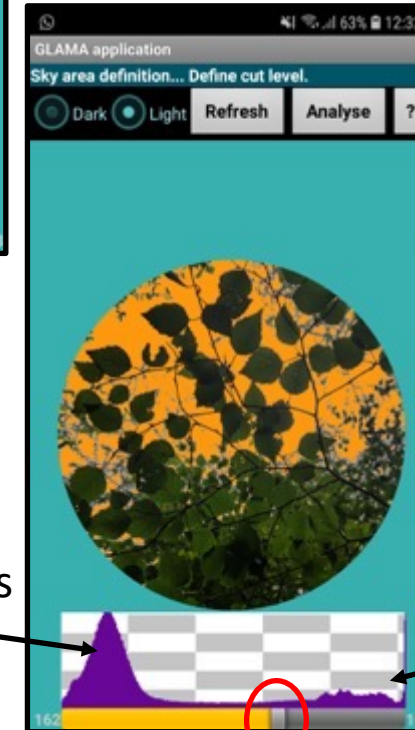
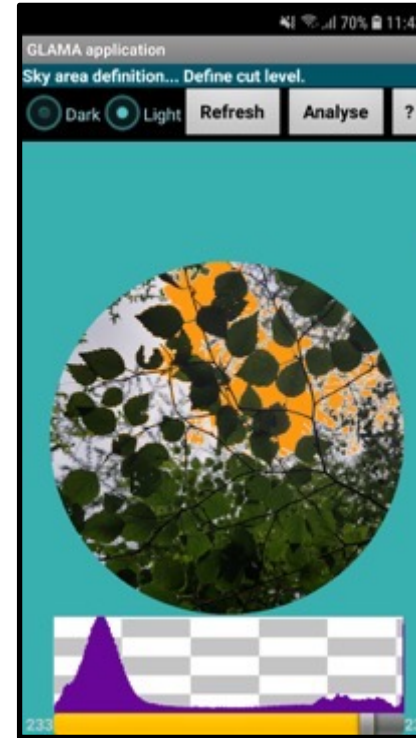
STEP 7: ANALYSING THE PHOTOS USING GLAMA

On the 'Sky area definition' page, you can manually govern the classification between sky and canopy pixels.

Slide the bar at the bottom gradually until you obtain best separation between the sky and canopy areas.

Make sure you keep 'Refreshing' every time you change the cut level value.

You can zoom and hover over the image to check the classification by touching different parts of the picture.



Canopy pixels

Sky pixels

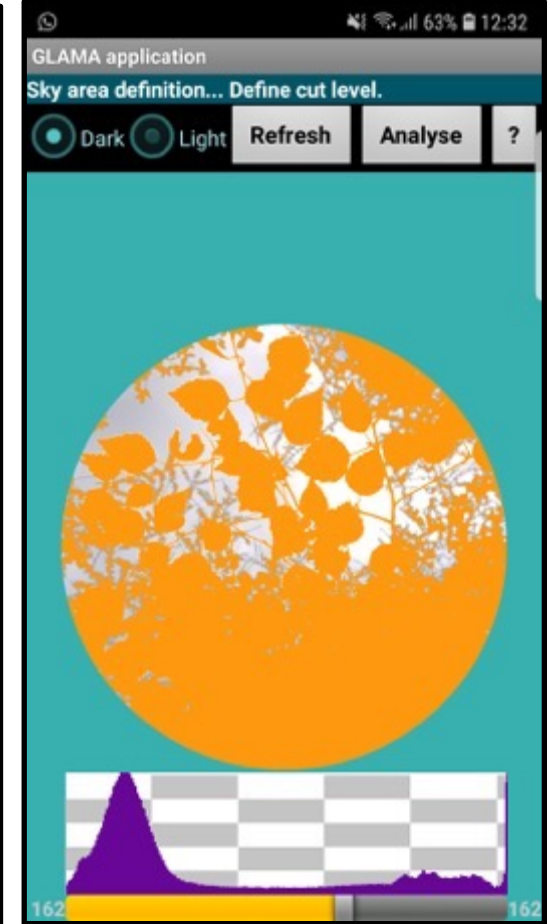
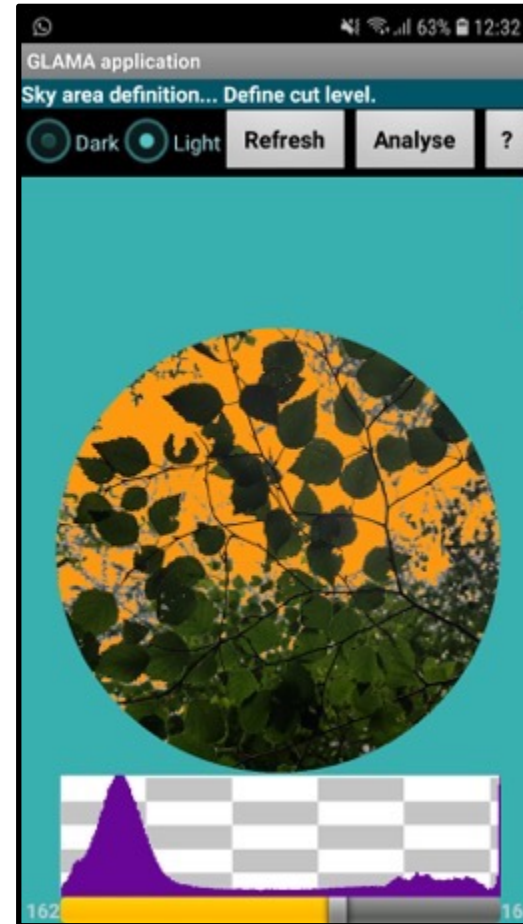
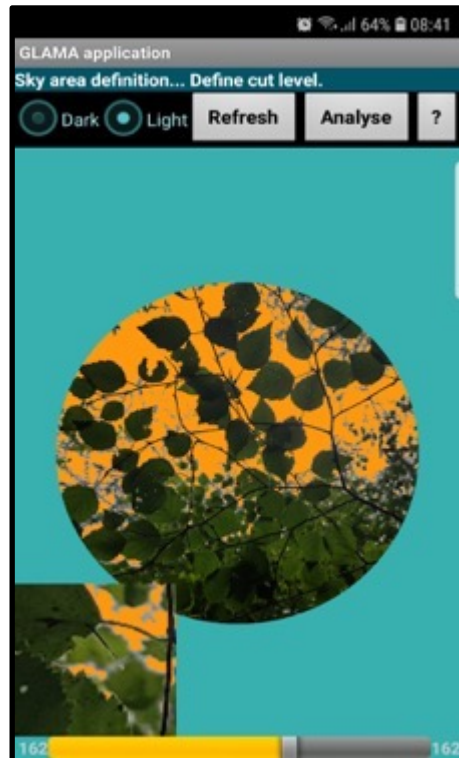
Separation 'cut level' between canopy and sky

STEP 7: ANALYSING THE PHOTOS USING GLAMA

In general, the region of the histogram with the lesser number of pixels (in between two peaks and separating canopy and sky), is ideal for defining the cut level.

You can always flip between Dark and Light buttons on the 'Sky area definition' page to carefully check the quality of separation between canopy and sky.

You can zoom and hover over the image to check the classification by touching different parts of the picture.



STEP 7: ANALYSING THE PHOTOS USING GLAMA

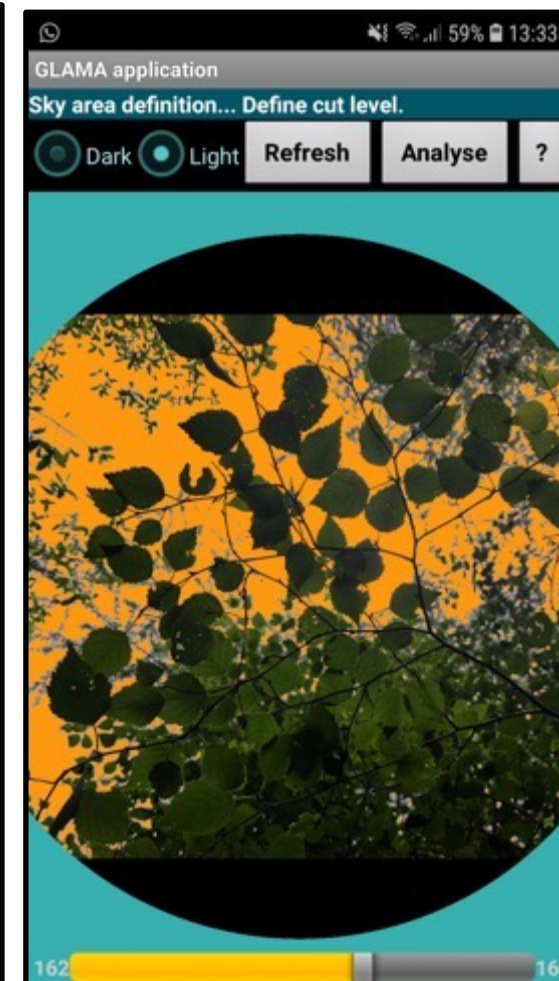
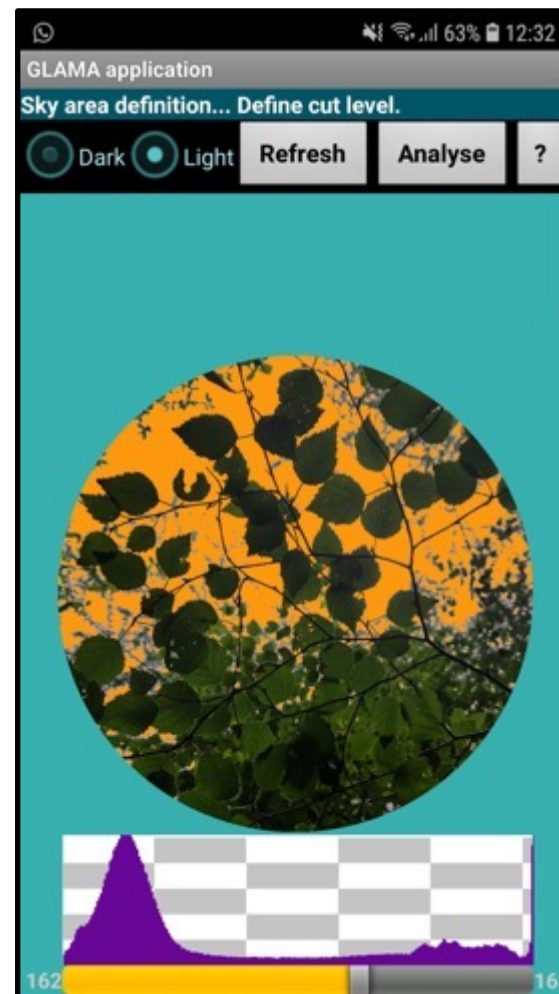
Important point to note while you analyze pictures using GLAMA.

- At the step where you are defining the ‘**Cut level**’, make sure your circular area of the image is properly covered by the **green** background.

In other words, your circular field of view **should not overflow** beyond the edges of the green box.

- In the second case, you may have to set the mask value higher than 70° on the ‘Horizon definition, preciseness, channels’ page.

Once you choose a suitable value, use it throughout and for all the pictures.



STEP 7: ANALYSING THE PHOTOS USING GLAMA

Once you are happy with the 'Cut Level'
Click on the NEXT button to get to the Result page.

The 'Modified CaCo Index' is the corrected Canopy Cover value you should record.

Make note of the 'Modif. CaCo Index' and cut level value.

Note down these readings against the plot ID and photo number you are analyzing.

FILE: 20190709_125945

Results...

Params	Back	Save	New	?
Total No. of Pixels in Circle (in Frame)	12229369 px (1688148 px)	No. of Light (Dark) Pixels	154207 px (12075162 px)	
Gap Fraction of Selected Area		1.26%		
Part of Hemisph. Taken by Camera	58.77%	Cut Level between Black and White Pixels (1-254)	162	
Canopy Openness	Open sky area / whole hemisphere area 5.49%	Canopy Closure	Obstructed sky area / whole hemisphere 94.51%	
Canopy Cover (CaCo) Index	Estimated canopy cover in vegetation surveys 73.38%	Modif. CaCo Index	More robust and less sensitive to uneven gaps near horizon 73.37%	

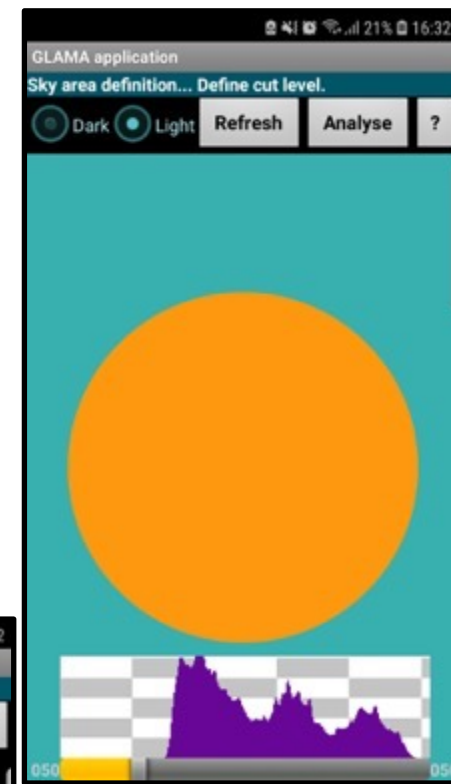
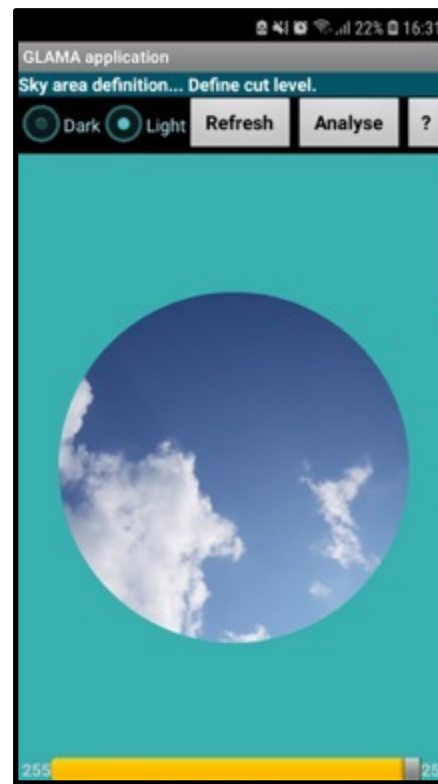
STEP 7: ANALYSING THE PHOTOS USING GLAMA

Through the canopy cover campaign, we aim to capture variability in different forest types throughout Wales. So we should capture data from stands with varying canopy density.

If you are particularly capturing pictures from open woodland stand, some of your pictures may only have sky.

Do not avoid such pictures. You should adjust the cut level so as to get 0% canopy cover for that picture.

It is an important piece of information for the average canopy cover estimate for the plot...



Params	Back	Save	New	?
Total No. of Pixels in Circle (in Frame) 12229369 px (1688148 px)				
No. of Light (Dark) Pixels 603759 px (11625610 px)				
Gap Fraction of Selected Area 4.94%				
Part of Hemisph. Taken by Camera 58.77%				
Cut Level between Black and White Pixels (1-254) 050				
Canopy Openness Open sky area / whole hemisphere area 21.48%				
Canopy Closure Obstructed sky area / whole hemisphere 78.52%				
Canopy Cover (CaCo) Index Estimated canopy cover in vegetation surveys 0.00%				
Modif. CaCo Index More robust and less sensitive to uneven gaps near horizon 0.00%				

STEP 7: CONTRIBUTE YOUR DATA

Once you reach the final analysis step with results, Click on **Save** button.

It will ask for 'ID code'

You can choose any code, e.g. 1,2,3,4..

Or p1,p2,p3, etc. or associated EarthTrack site name (e.g. Wye valley 1, 2, 3, etc)

Or even the time-tag of the picture (e.g. see the screenshot)

All the results get written in the 'results.txt' file.

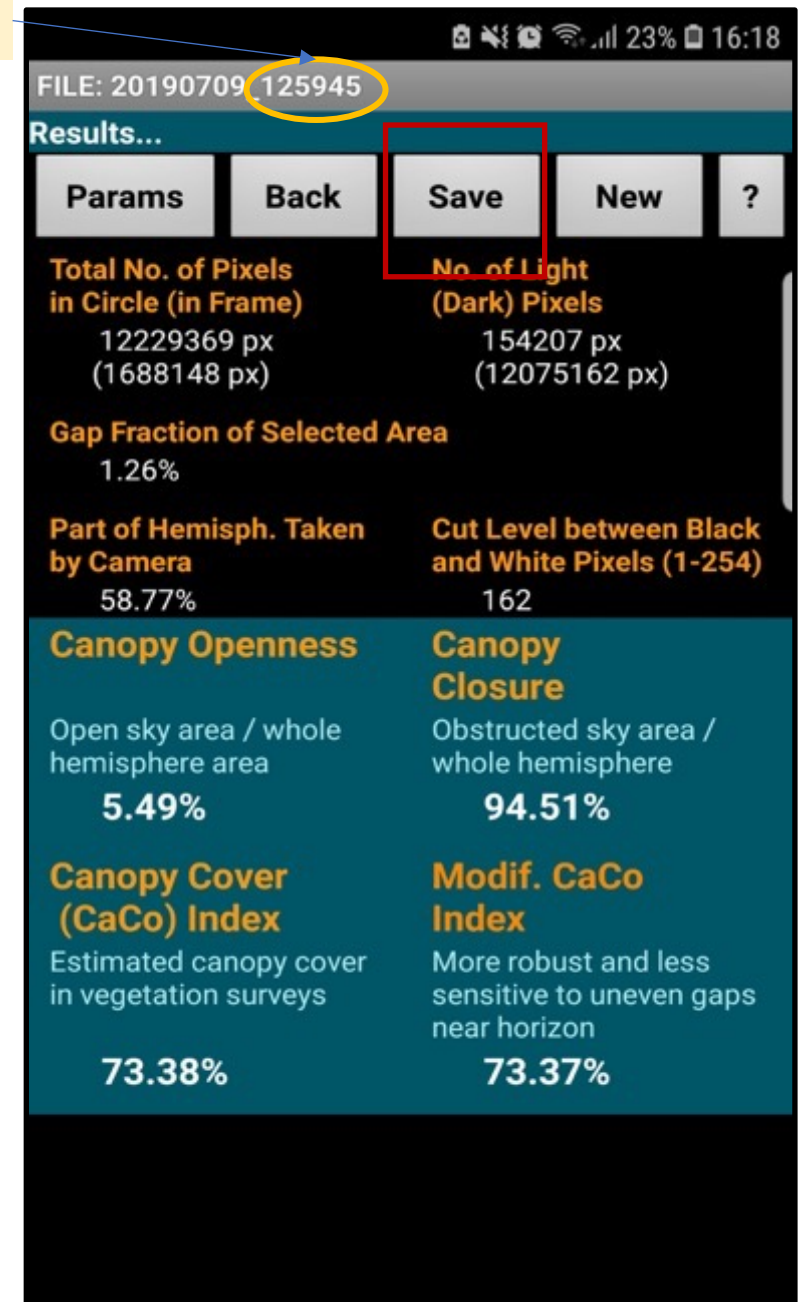
This is generally located in the following folder
'My Files/Internal storage/images'

No need to create new file for new plots as it just gets appended with new records. Once you think you have done enough measurements, send across this file to '**smp15@aber.ac.uk**' with subject line : '**GLAMA measurements**'

Also let us know your EarthTrack pseudonym, so that we can relate these measurements with appropriate LCCS point.

It is helpful if you could also send all your pictures to the same email id for some cross-checking, however is not must.

Time-tag



SUMMARY

The Canopy cover campaign organized by the Living Wales project invites everybody in Wales to contribute field data relating to maximum tree canopy cover, with this measured using mobile app called GLAMA. The app can be downloaded from the google play store.

The app can be used in conjunction with another app called 'Level Camera' which helps to take vertically upward looking pictures in from a levelled (horizontal) orientation. Level Camera is also available on the google Play Store.

The land cover information for the observation plot should be recorded with the EarthTrack app, available to download from <https://earthtrack.aber.ac.uk/>.

The campaign will run through August 2021.

For further information contact:

Dr. Suvarna Punalekar (smp15@aber.ac.uk)

Prof Richard Lucas (richard.lucas@aber.ac.uk)



Some tips

1. It may be useful to take a random side looking picture at the beginning and end of the plot, so that you can keep track of 9 pictures.
2. If you are working in pair and have two android phones, one person can record EarthTrack while the other does GLAMA. This helps to make the process quick. Let us know the EarthTrack pseudonym of a person recording the EarthTrack point.
3. If you are an **iPhone user**, you won't be able to perform GLAMA analysis. However, you can still contribute by taking horizontal pictures and send them across to us. For horizontal alignment check, iPhone offers inbuilt function.
4. Recommended cut levels are generally good enough; however always check the quality of masking in the analysis. For certain pictures (e.g. those with leaves appearing bright due to reflected or transmitted sunlight). you may have to change it significantly (see screenshots for example).

It is a good approach to keep the cut level in-between two peaks of the histogram.

