Measuring forest canopies with smartphones

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1.Introduction

Traditional methods to measure canopy variables like densiometers are crude. Hemispherical photography is much more accurate, but requires expensive equipment like digital single-lens reflex cameras (DSLR) and specialized lenses, is tedious to deploy, and extremely prone to errors due to poor exposure.

In contrast, modern smartphone cameras are readily available and make use of ever-improving software to produce images with high dynamic range and clarity, but lack suitable hemispherical lenses. Thus, despite the fact that almost all ecologists and foresters carry a high-powered, image processing device in our pockets, we have yet to fully employ it for the purpose of data collection.

Here, I developed method to extract hemispherical images from spherical panorama software available on any smartphone that is easy to implement, requires no additional equipment, and is more accurate than traditional methods.

2.Methods

Example of capturing a photosphere with a smartphone guided by the phone's spatial mapping prompts. Image from: www.maketecheasier.com/make-good-use-of-smartphone-camera/

Google Camera app (for Google phones) or Google Street View (for Android and iOS) is used to capture a spherical panorama following the app's onscreen prompts.

The phone uses computational photography and high dynamic range routines to ensure even exposure in all 36 images that make up the photosphere. Then, the software automatically stiches the images into a single, seamless panorama.

Extracting circular hemispherical images from photospheres requires just a single line of code. (I provide command line scripts and also recopies for batch processing images with an open source GUI platform in the supplementary material).

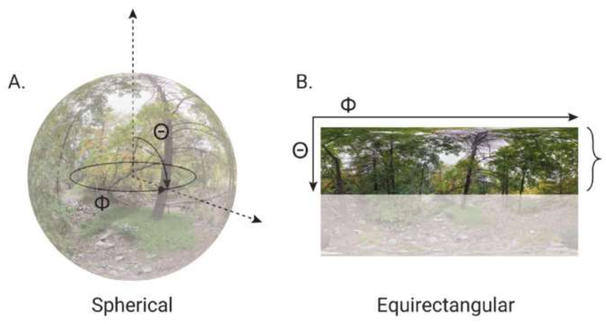


Figure 1. Spherical panoramas (A) are stored and output from smartphones as 2D images with equirectangular projection (B). Because spherical panoramas are automatically leveled using the phone gyroscope, the top half of the equirectangular image corresponds to the upper hemisphere of the spherical panorama. The top portion of the equirectangular image (B) can then be remapped onto the polar coordinate plane to create a circular hemispherical photo (C). In all images, zenith and azimuth are indicated by Θ and Φ, respectively.

I compared full-resolution smartphone images (SSP_{Full}) to traditional DSLR images. I also compared a method with a clip-on fisheye phone lens proposed by Bianchi et al. (2007). To evaluate the effect of image quality versus resolution, I compared smartphone images downsampled to DSLR resolution (SSP_{Low}). I also compared a set of over- and under-exposed images to evaluate exposure quality.

3. Results

Benefits of smartphone images:

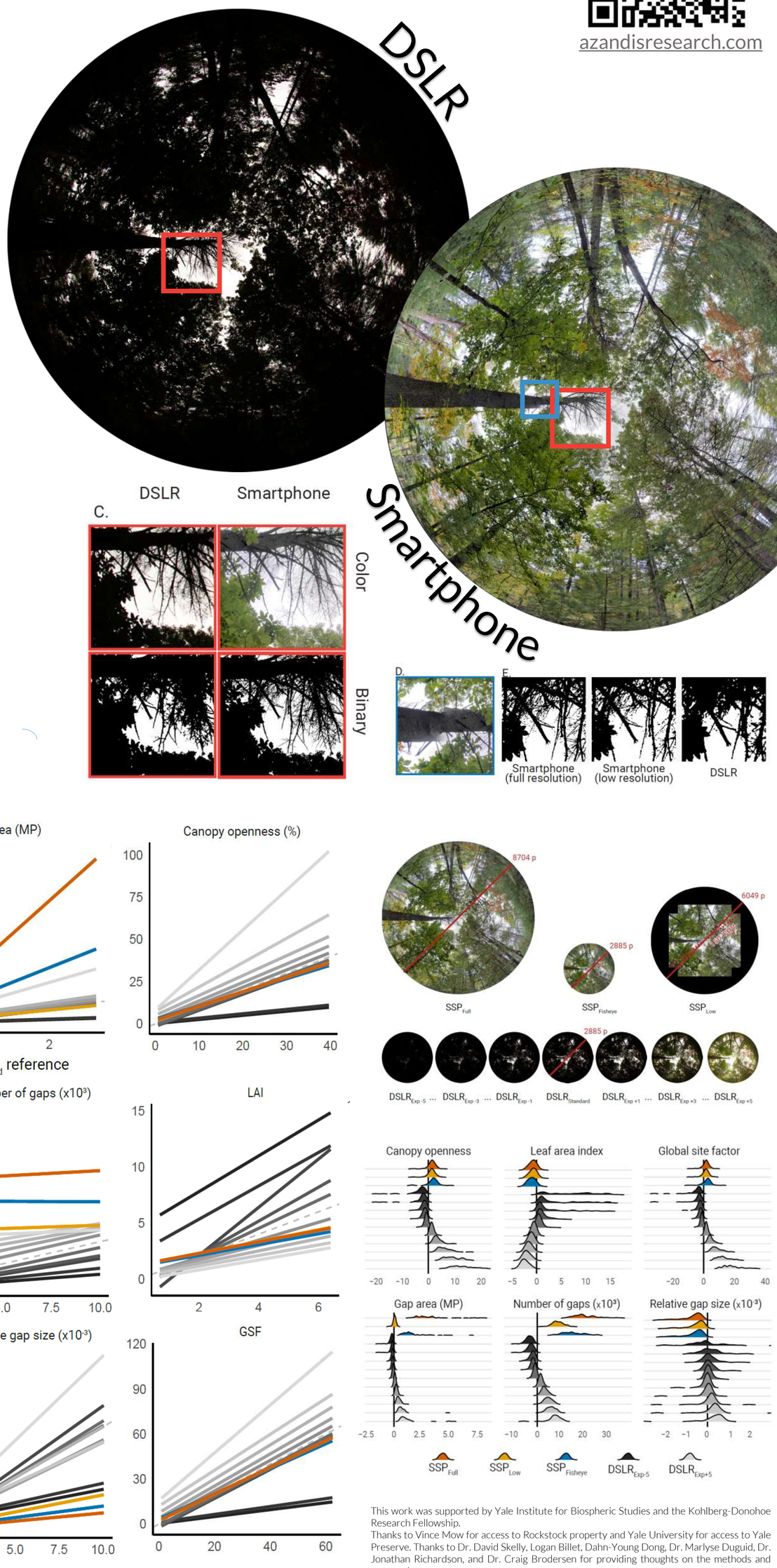
- 900% greater resolution than DSLR images
- More accurate depiction of canopy elements and retention of fine canopy gaps
- Reduced exposure errors in suboptimal light conditions
- Even exposure automatically
- Automatic levelling
- Compass direction, elevation, and geolocation stored in metadata
- Consistent polar projection across platforms
- Smartphones are easy to "field-proof" (i.e. waterproof, durable)
- Plus, additional benefits of photospheres (virtual reality, tree stand mapping, record of understory, etc.)

Potential problems:

- Shifting the camera produces artifacts during stitching
- Quality difference between phone platforms

Methods comparison:

Estimates of canopy openness and global site factor (i.e. understory radiation) are over 90% correlated with DSLR estimates. Leaf area index estimates are over 70% correlated, but differ in darker canopies. Most of this difference is due to DSLR images underestimating fine canopy structure. Because smartphone images have higher resolution and better exposure, especially in low light and dense canopies.



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