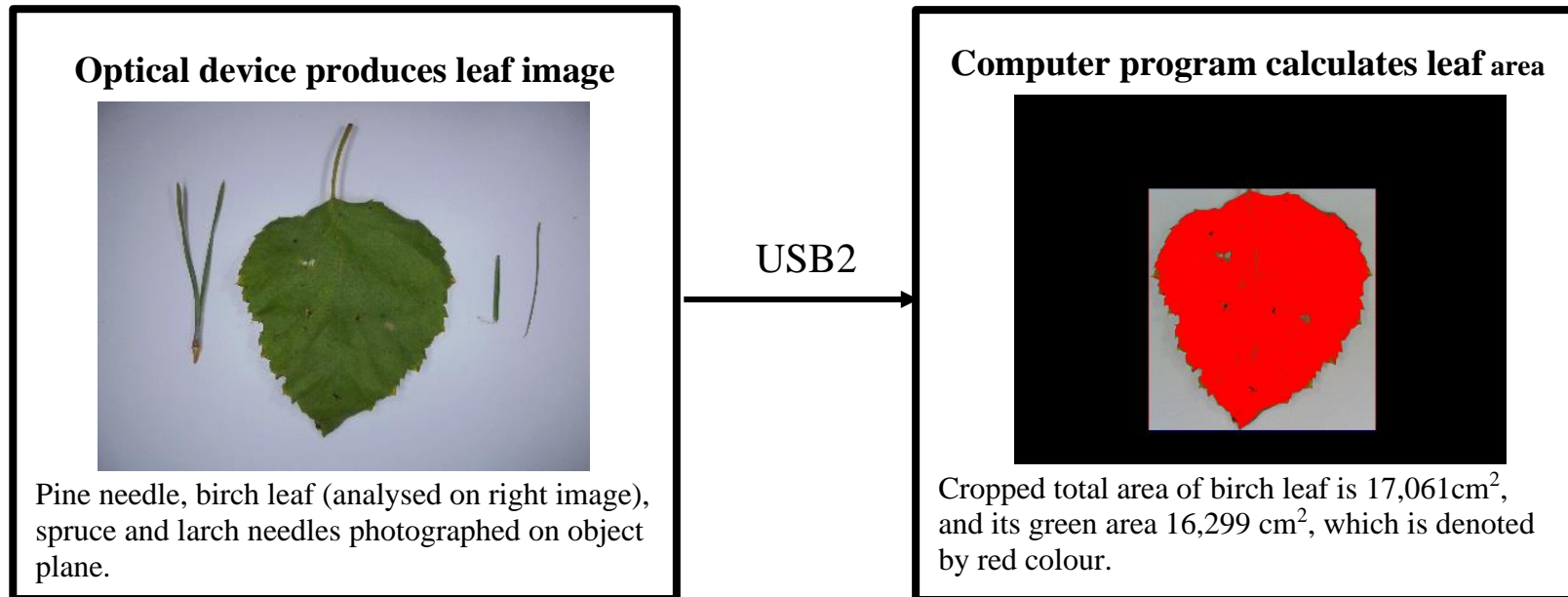




"Simatec - Revealing future of measuring"<sup>1</sup>

## Leaf area meter (LePaM -v1)



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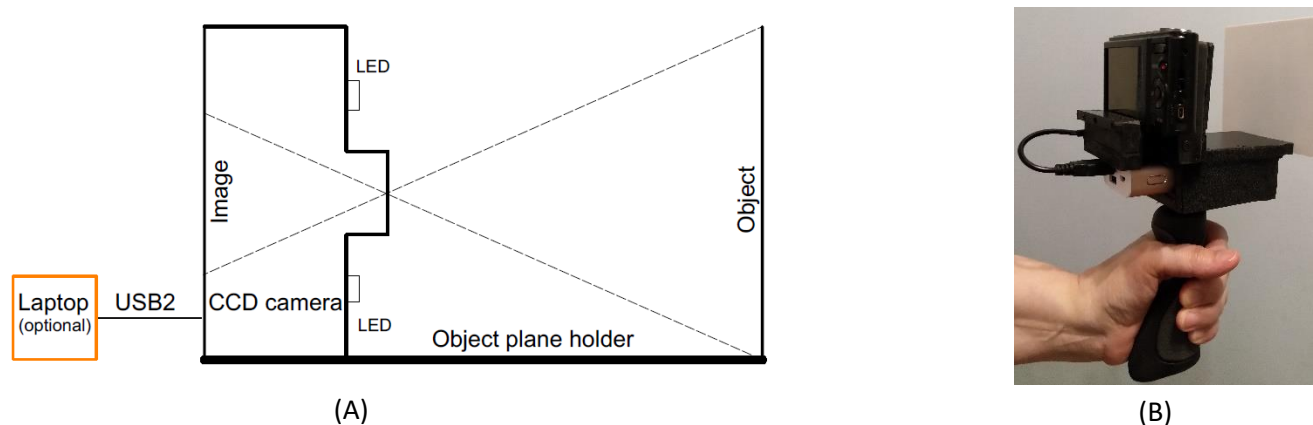
## Leaf area meter (LePaM -v1)

### Introduction:

Today, carbon sequestration in the flora has emerged in the monitoring and management of the state of the environment. One such monitoring method is to measure the amount of chlorophyll. The chlorophyll absorbs carbon dioxide in the air and reciprocally releases oxygen into the atmosphere, this process uses absorption of electromagnetic radiation or adsorption of photons. Color green, is assumed to relate chlorophyll in the leaves.

### Optical Device that produces Leaf Image (ODLI):

The operation of the leaf area meter is based on the use of a camera as shown in figure 1 below <sup>[2]</sup>.

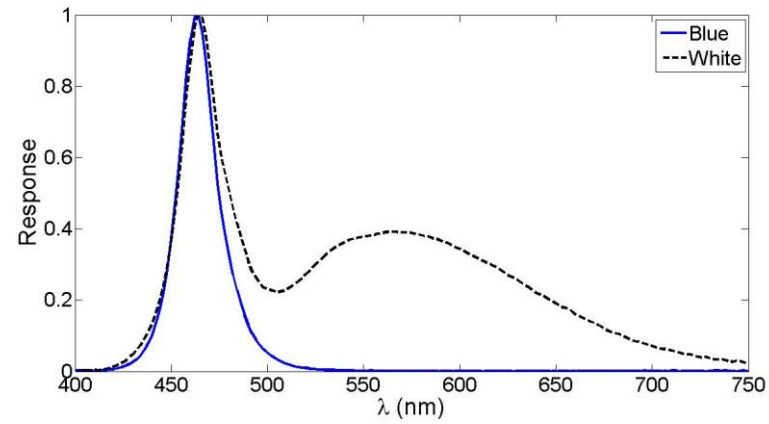


**Fig. 1.** (A) An illustration of the principle of the LePaM-v1 meter and (B) its implementation (ODLI).

In this version, the camera's own flash is not used to expose the sample because the light-scatter produced by it at an object plane 100mm away is not symmetrical. Due to this, it was decided to use four (40 cd) white (colour temperature 10000K) light emitting LEDs in the structure. The LEDs were placed symmetrically around the lens with a spacing of 37 mm vertically and 66 mm horizontally. In practice, the LED light is produced through fluorescence, where the excitation light is blue (Fig. 2).

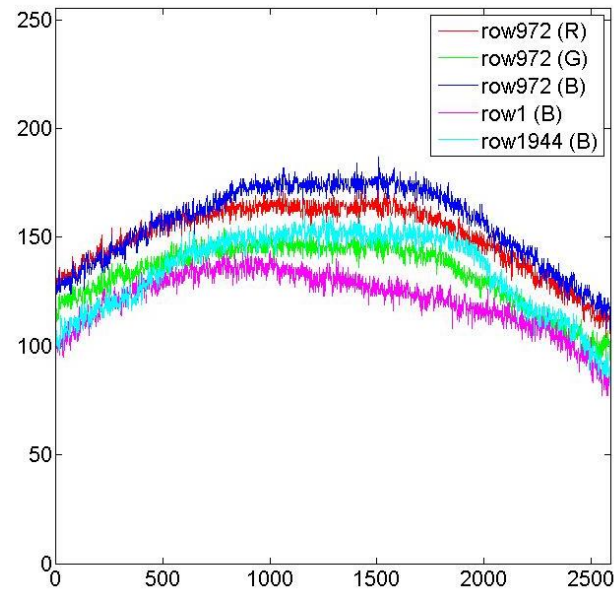
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<sup>[2]</sup> This method works on the principle of reflection, because the object is illuminated with LED light sources. The method is based on the use of leaf green i.e. chlorophyll a and b absorption zones. In these wavelength ranges, leaf reflection is minimal. Image data is transferred to a computer for area calculation via USB2.



**Fig. 2.** White LED light is obtained, when a blue LED is coated with a fluorescent substance that is excited by blue (“Blue”) light to emit white light (“White”) at longer wavelengths.

What is interesting here is that in photometric quantities, the blue tuning light is not visible, but it is visible in the camera image.



**Fig. 3.** R, G, and B lighting distributions printed from the top, middle, and bottom rows of the background image (5M). The numbers on  $x$  axis represent pixels,  $y$  axis is value registered with camera.

It can be seen from figure 3 that in LED illumination on image plane, the light distribution is now symmetrical compared to the lighting provided by flash. On the spectral side, the blue B-channel is highlighted compared to the *R* and *G* channels. Because of the white light ( $T = 10000\text{K}$ ) in use, the differences are now not significant. Utilizing four 40cd white LED's, the illuminance at the object plane is c.a. 3000 lux.

The available image sizes are listed in Table 1.

**Table 1.** Pixel size at object plane, distance of 75 mm from objective front surface.  
An aspect ratio of 16 : 9 is not recommended.

No	Size	Aspect ratio	jpg- image size <sup>[3]</sup>	Pixel size ( $\mu\text{m}$ )
1	20M	4:3	3864×5152×3	21.2
2	10M	4:3	2736×3648×3	29.8
3	5M	4:3	1944×2592×3	42.0
4	VGA	4:3	480×640×3	172.0
5	15M	16:9	2896×5152×3	21.2
6	2M	16:9	1080×1920×3	57.4

#### Mechanical properties:

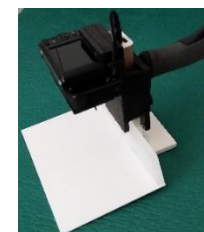
- dimension: 180mm × 120 × 260mm (L×W×H, Fig.1)
- weight ca. 0.8 kg
- protection class IP20

#### Output:

- signals (*R*, *G*, *B* jpg -images) through USB2 cable to computer.

#### Measuring ranges:

- size of diffuse white sample plane of ODLI is 120mm × 90mm to cover the image size of 108mm × 83mm. The pixel size depends on image size as shown in Table 1.
- size of diffuse white sample plate can be extended.
- An example of ODLI extension is shown in figure 4 <sup>[4]</sup>.



**Fig. 4.** ODLI extension.

<sup>[3]</sup> With an aspect ratio of 4: 3, the LePaM -v1 meter produce an image from object surface covering size of 108mm × 81mm and with an aspect ratio of 16 : 9 it is 108mm × 60.7mm. LePaM -v1 can be manufactured also according to the customer's needs.

<sup>[4]</sup> According to the customers need, the size of sample plane can be extended to be 240mm × 180mm for 20M image keeping the pixel size of 40 $\mu\text{m}$  (c.f. Table 1). If the pixel size of 80  $\mu\text{m}$  is accepted, so the sample plane can be extended to be 480mm × 360mm for 20M image.

**Environment:**

- operating temperature 0 - 40 °C.
- storage temperature -20 - 80 °C.
- use of ambient humidity non-condensing 20 - 80%.
- storage environment humidity non-condensing 10 - 90%.
- leaf area measurements under laboratory conditions, where the level of illuminance is typically between 100 and 300 lux. Since the illuminance at the white object level is 3000 lux, the effect of the backlight is not significant.
- leaf area measurements work in field conditions in cloudy weather, where the illumination intensity is between 5 000 and 10 000 lux. In this case, the light coming on the white object plane is diffuse and shadows detrimental to the photography are not easily increased.
- direct sunlight (~ 100,000 lux) entering the white image plane can cause saturation of the camera cell and distortion of the leaf area measurement result. As a result, in field measurements, direct sunlight must be removed by a shade.

**Calibration:**

- manufacturer takes care of ODLI calibration. If customer uses their own device to produce leaf image, the manufacturer does not guarantee the accuracy of the calibration without the calibration agreed upon by the manufacturer.

**Computer (Option):**

- matte 15.6 "HD WLED display (1920x1080) or better
- 5th generation Intel Core i5 2 core processor (max 2.70GHz) or equivalent
- Integrated Intel HD Graphics 5500 graphics card or better with at least 8GB of DDR3L memory or more
- 256GB SSD hard disk or larger
- WLAN and Bluetooth 4.0
- HDMI connector
- 2 USB 3.0 and 1 USB 2.0 connectors
- Gigabit Ethernet (RJ-45) network interface
- Windows 10 operating system 64bit

**Computer Program that calculates Leaf Area (CPLA):**

The program examines the relationships between the  $R$ ,  $G$ ,  $B$  components of the jpg image in colour additive domain. In first round, the  $R$ ,  $G$ ,  $B$  are the same as read from CCD display. This is done by using the relation  $R = G = B = 1$ . However, in some cases, the weighing of  $R$ ,  $G$ ,  $B$  components is needed to achieve reasonable result. Thus, RGB colour specific coefficients  $k_R$ ,  $k_G$  and  $k_B$  are used, and coefficients  $a$ ,  $b$  and  $c$  are used to modify overall brightness, black level and gamma of signal image as follows

$$R_S = a \times (RS_{CCD} \times k_{RS})^c + b \quad (1a)$$

$$G_S = a \times (GS_{CCD} \times k_{GS})^c + b \quad (1b)$$

$$B_S = a \times (BS_{CCD} \times k_{BS})^c + b. \quad (1c)$$

Whereas, the colour-specific background (values with  $b$  sign) correction can be performed as

$$R_{cor} = (RS_{CCD} \times k_{RS}) / (Rb_{CCD} \times k_{Rb}) \quad (2a)$$

$$G_{cor} = (GS_{CCD} \times k_{GS}) / (Gb_{CCD} \times k_{Gb}) \quad (2b)$$

$$B_{cor} = (BS_{CCD} \times k_{BS}) / (Rb_{CCD} \times k_{Bb}). \quad (2c)$$

and

$$R_S = a \times (R_{cor})^c + b \quad (3a)$$

$$G_S = a \times (G_{cor})^c + b \quad (3b)$$

$$B_S = a \times (B_{cor})^c + b. \quad (3c)$$

If grey scale is selected, so

$$R_S = a \times (RS_{CCD} \times k_{RS} + GS_{CCD} \times k_{GS} + BS_{CCD} \times k_{BS}) \quad (4a)$$

$$G_S = R_S \quad (4b)$$

$$B_S = R_S. \quad (4c)$$

If the grey level is selected, then the background correction is performed to be

$$R_S = a \times \left( \frac{RS_{CCD} \times k_{RS} + GS_{CCD} \times k_{GS} + BS_{CCD} \times k_{BS}}{Rb_{CCD} \times k_{Rb} + Gb_{CCD} \times k_{Gb} + Bb_{CCD} \times k_{Bb}} \right)^c + b \quad (5a)$$

$$G_S = R_S \quad (5b)$$

$$B_S = R_S. \quad (5c)$$



**Fig. 5.** LePaM -v1 computer program icon. Utilizing this it is possible to measure distances and calculate leaf areas.

Next short introduction what is behind the buttons (c.f. Figs. 6a, 6b and 6c).

Lehden pinta-alamittari

Suomi

Signal	Background
2592	2592
1944	1944

Binarize

0,35 Start

0,5 Magnification 0,48 End

Selection of language (Finnish, English)

Load signal image and its background

Pixel number of signal and background in x-direction

Pixel number of signal and background in y-direction

Magnification of image on desktop

**Fig. 6a.** Selection of language, data loading with size information and desktop magnification. Selection buttons “Binarize”, “Start” and “End” are related to color band selection.

Execute	Execute color band
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Normalize 0,0

Background correction

False color

Normalize

Gray scale

Invert

.5 Coefficient a

0 Coefficient b

1 Coefficient c

1 R	1 R
1 G	1 G
1 B	1 B

Threshold 0,6

Binarize

When the function is selected, Execute or Execute color band program

C.f. Equations (1) – (5)

Threshold selection for binarization of image

**Fig. 6b.** In addition of basic image operators (as background correction, false color, normalize, grey scale, invert, threshold and binarize), running the program when the required functions have been selected. Threshold area calculation needs image to be inverted, with invert checkbox.

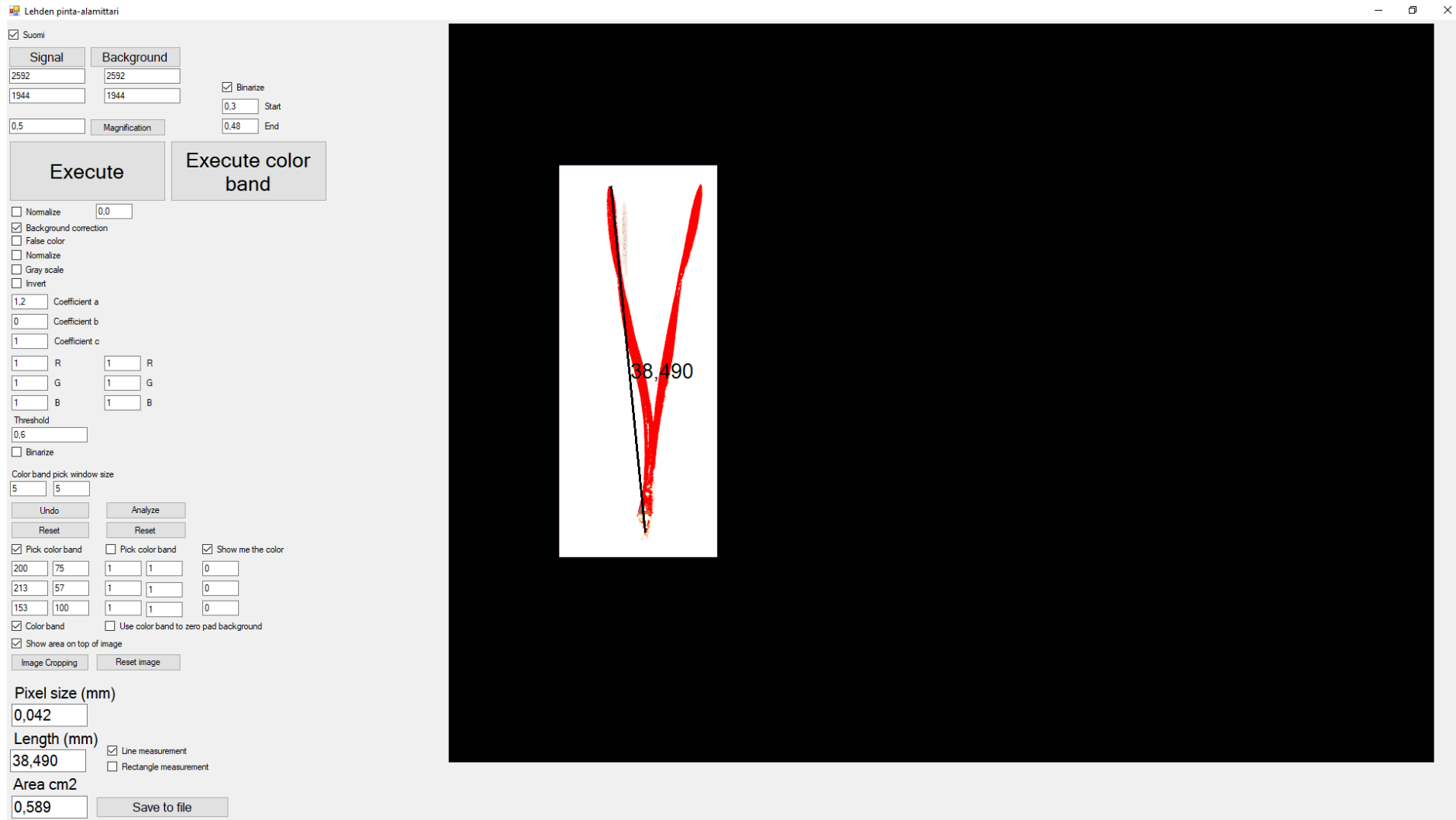


In figure 6c colour band textboxes on left are averaged  $R$ ,  $G$  and  $B$ , and on the right  $\delta R$ ,  $\delta G$  and  $\delta B$ . Colour band values can be retrieved from image by selecting checkbox pick colour band pressing image where desired colour is locating, image can be clicked many times. When colour band checkbox is selected then program calculates image area, where this colour band has values. To be able to see, where a leaf is then checkbox show on top of image is useful.

**Fig. 6c.** Parameter for colour band analysis, image cropping, distance and area measurement, and moreover length and area for the sample. If metric units are to be used, the pixel size must be known.

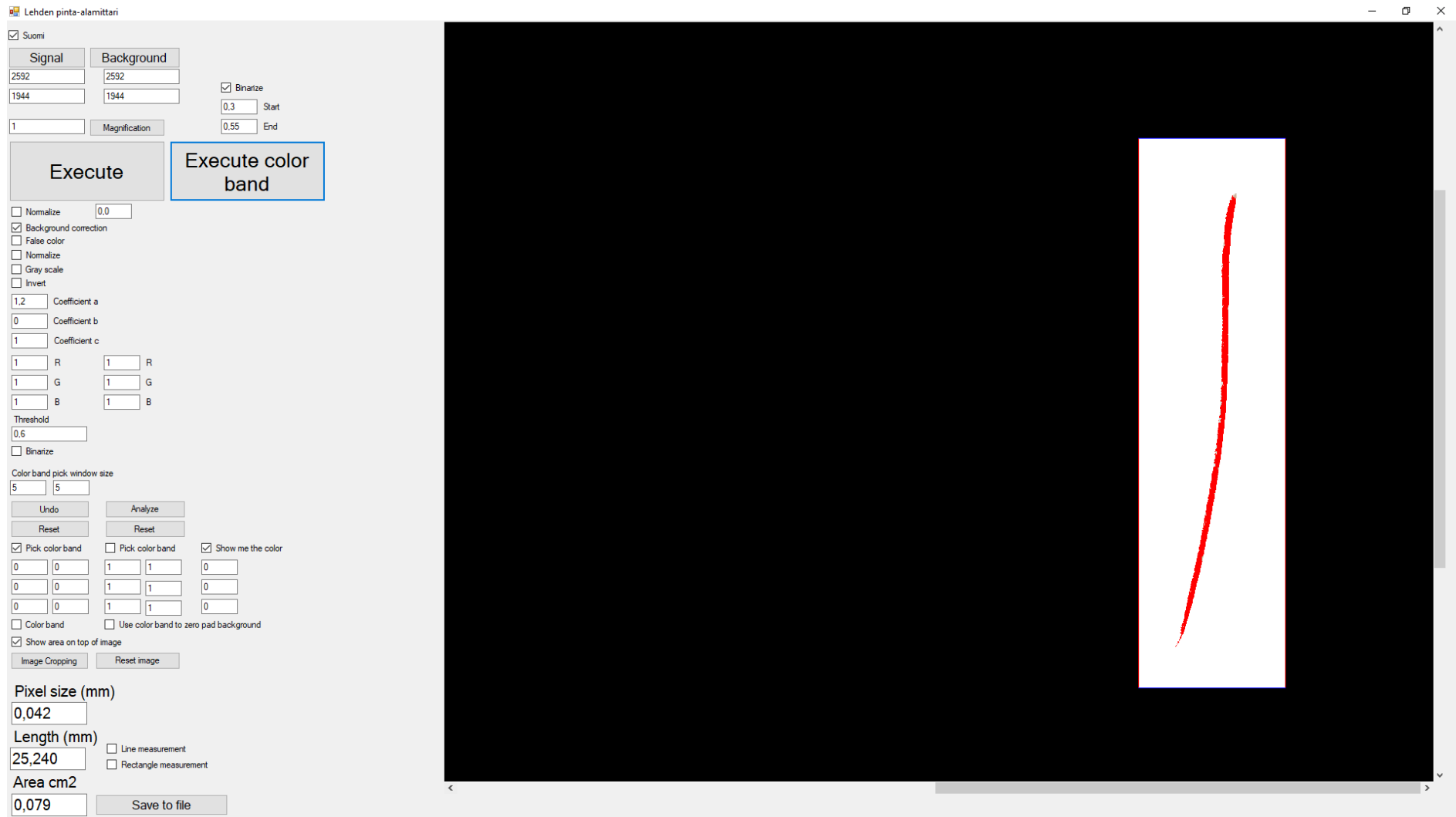
Example 1 and 2 deals with the analysis of a pine and larch needle shown in Fig. 5. The mean results of analysis of a birch leaf is already presented in the illustration on the front page of this product release.

**Example 1:** Analysis of a pine needle is performed and it is shown in figure 7.



**Fig.7.** After analysis of RGB - jpg image gained from larch needle indicates that the length of needle is 38.490 mm and its area 0.589 cm<sup>2</sup>.

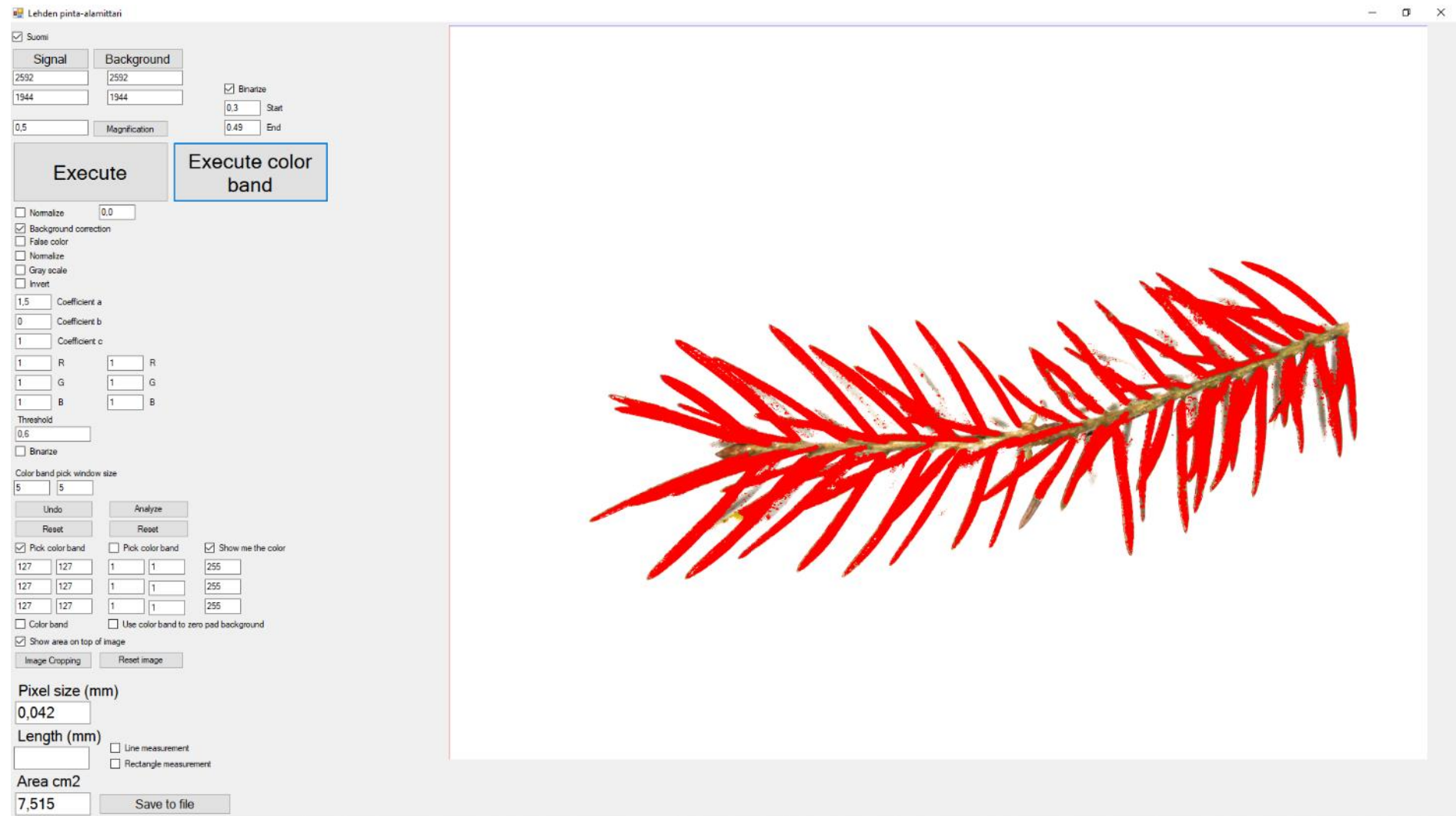
**Example 2:** Analysis of a larch needle is performed and it is shown in figure 8.



**Fig.8.** After analysis of RGB - jpg image gained from larch needle indicates that the length of needle is 25.240 mm and its area 0.079 cm<sup>2</sup>.

The CPLA also allows for Local Image Magnification Correction (LIMC), if the height of the object deviates significantly from a fixed object plane in the direction of the camera's optical axis. Details can be found in the user manual.

**Example 3:** Study of the shading effect on a spruce branch presented with figures 8a and 8b.



**Fig. 9a.** A spruce branch, which length is 71.828mm and area of needles 7.515cm<sup>2</sup> without LIMC.



**Fig. 9b.** Needles separated from the trunk of a spruce branch, which is shown in Fig. 8a. Needle area is 8.155 cm<sup>2</sup>, which indicates that magnitude of shading effect is  $(1-7.515\text{cm}^2/8.155\text{cm}^2)\times 100\% \sim 7.8\%$ .

## RECOMMENDED CUSTOMER GROUP

- Industry and companies
- Universities and Research Institutes

## PRICE

LePaM -v1 consists of three main blocks: 1) the device that produces the image of a leaf, 2) the computer program that calculates the area of that leaf in 3) Laptop:

1. ODLI: Device that produces the image, power supply and USB2 cable for image data transfer and camera battery charging AC/DC adapter (AC230V/50Hz to DC5V) 1500,00 € <sup>[5]</sup>.
2. CPLA: Installation media and operating license 2000,00 € (Software and license for software of measuring instrument) <sup>[6]</sup>.
3. Laptop (Option):
  - matte 15.6 "HD WLED display (1920x1080) or better
  - 5th generation Intel Core i5 2 core processor (max 2.70GHz) or equivalent
  - Integrated Intel HD Graphics 5500 graphics card or better with at least 8GB of DDR3L memory or more
  - 256GB SSD hard disk or larger
  - WLAN and Bluetooth 4.0
  - HDMI connector
  - 2 USB 3.0 and 1 USB 2.0 connectors
  - Ethernet (RJ-45) network interface
  - Windows 10 operating system 64bit

**IN TOTAL: 3500 € (VAT 0%) <sup>[7]</sup>; EXW Joensuu**

## Terms & Conditions

Equipment EXW JOENSUU (Incoterms 2010). Other terms and conditions according to TK Services 2010. The ownership of the supplied equipment will be transferred to the subscriber when the entire trade amount has been paid to the supplier. Equipment and work not mentioned in this offer and its annexes and other components are treated as additional work.

Delivery terms in the following order: 1. LePaM -v1 Price list, 2. TK Services 2010.

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<sup>5</sup> Due to the customers need, the extension of sample plane of LePaM -v1 will be charged according to a separate offer.

<sup>6</sup> For installation the software there exist several options: (i) The subscriber can do it first hand, (ii) The supplier can do it through a reliable internet connection, (iii) The subscriber purchases a laptop that meets the above minimum requirements and sends it to the vendor for software installation, or (iv) The supplier purchases the laptop, installs necessary software and invoices the subscriber separately for laptop price and installation work according to the Simitec Ltd service price list.

<sup>7</sup> Changes in prices are reserved.

**Transfer of risk**

The risk is transferred to the Subscriber when the goods are handed over to the subscriber or transported by an independent carrier in accordance with the contract, subject to the delivery clause.

If the item is not handed over at the right time and this is due to the fact that the Subscriber or the Subscriber is involved, the Liability shall be transferred to the Subscriber when the Supplier has done what he or she is required by the contract to enable the transfer.

**Delivery time**

Delivery time is agreed separately. The Agreement enters into force when the Subscriber's written order confirmation (including e-mail is accepted) has been received and confirmed from the Supplier's side to the Subscriber.

**Payment terms**

The terms of the offer are as follows. Late interest rate 10.5%.

60% when ordering the total price of item, 14 days net.

40% of the total price of item EXW, 14 days net

Additional work and any other supplies and equipment not included in the delivery will be billed after delivery, 14 days net.

**Warranty and maintenance**

The warranty for the devices to be delivered is 12 months from the time the equipment is ready for EXW. The warranty does not include travel and accommodation costs.

This offer includes LePaM -v1 for email and phone support for the warranty period without any charge. If the Subscriber makes his own changes to the LePaM -v1 system, the warranty will expire. The repair of the program is done by Simitec Ltd and the costs are invoiced according to the company's service price list and

they are charged 100% afterwards, 14 days net.

After the warranty period, the training, support and installation services and repair work will be billed according to the current Simitec Ltd service price list and will be charged afterwards at 100%, 14 days net.

For example, the cost of repairing a bug or installing an update will be charged on the basis of work hours and parts used for repair after work.

**Fee for additional work**

Additional and modifications must be agreed in advance and are based on a service price list. Other costs will be charged to actual amounts based on the Supplier's selling prices and terms and conditions set out in the Job Charging Pricing Schedule.