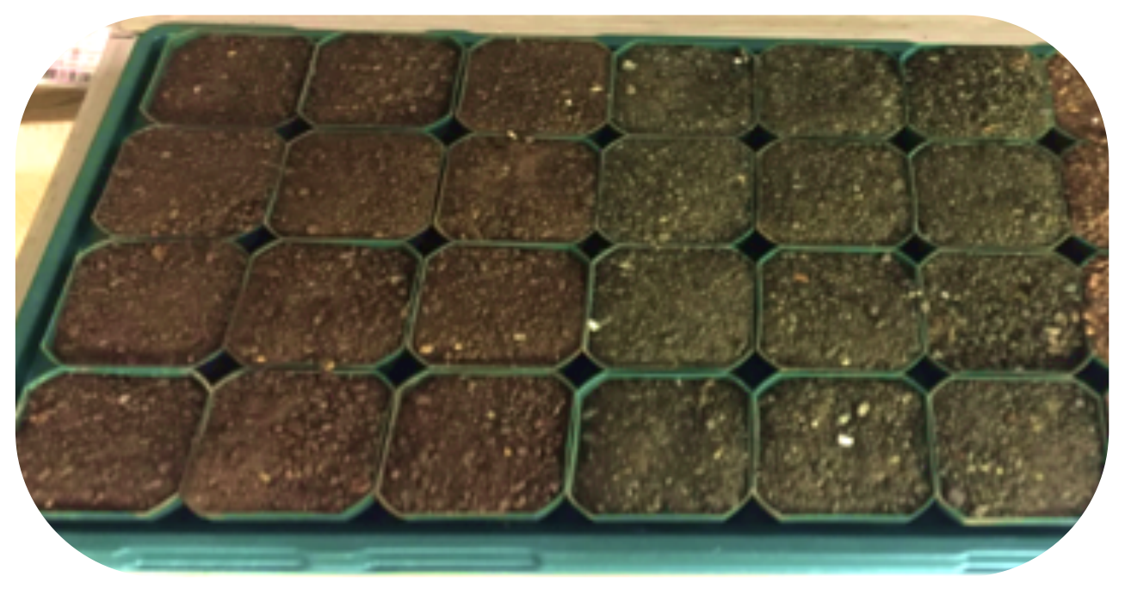
Studying the effects of serpentine soil on adapted and non-adapted species using Arduino technology

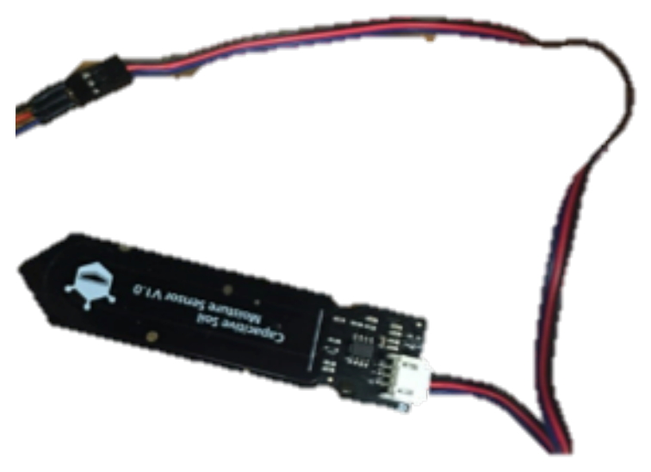
Kiana Saniee, Brian Paavo, Edward Himelblau

Biological Sciences, Cal Poly, San Luis Obispo, CA 93407

Introduction

Serpentine soil is of high interest to researchers in the ecological community. Serpentine soil represents harsh living conditions, including a lack of several essential nutrients, a low calcium to magnesium ratio, and high levels of certain metals. Despite these seemingly unsuitable conditions, some plants have adapted to serpentine soil and thrive in these challenging conditions. Our goal was to develop a lab-based system for analyzing plant growth in serpentine conditions. We examined soil moisture levels between commercial and serpentine soils (using *Arabidopsis thaliana* seeds) with Arduino technology consisting of soil moisture sensors. In addition, we collected data on photosynthetic activity of *Arabidopsis thaliana* seedlings planted in serpentine and commercial soils.





Soil Moisture Analysis

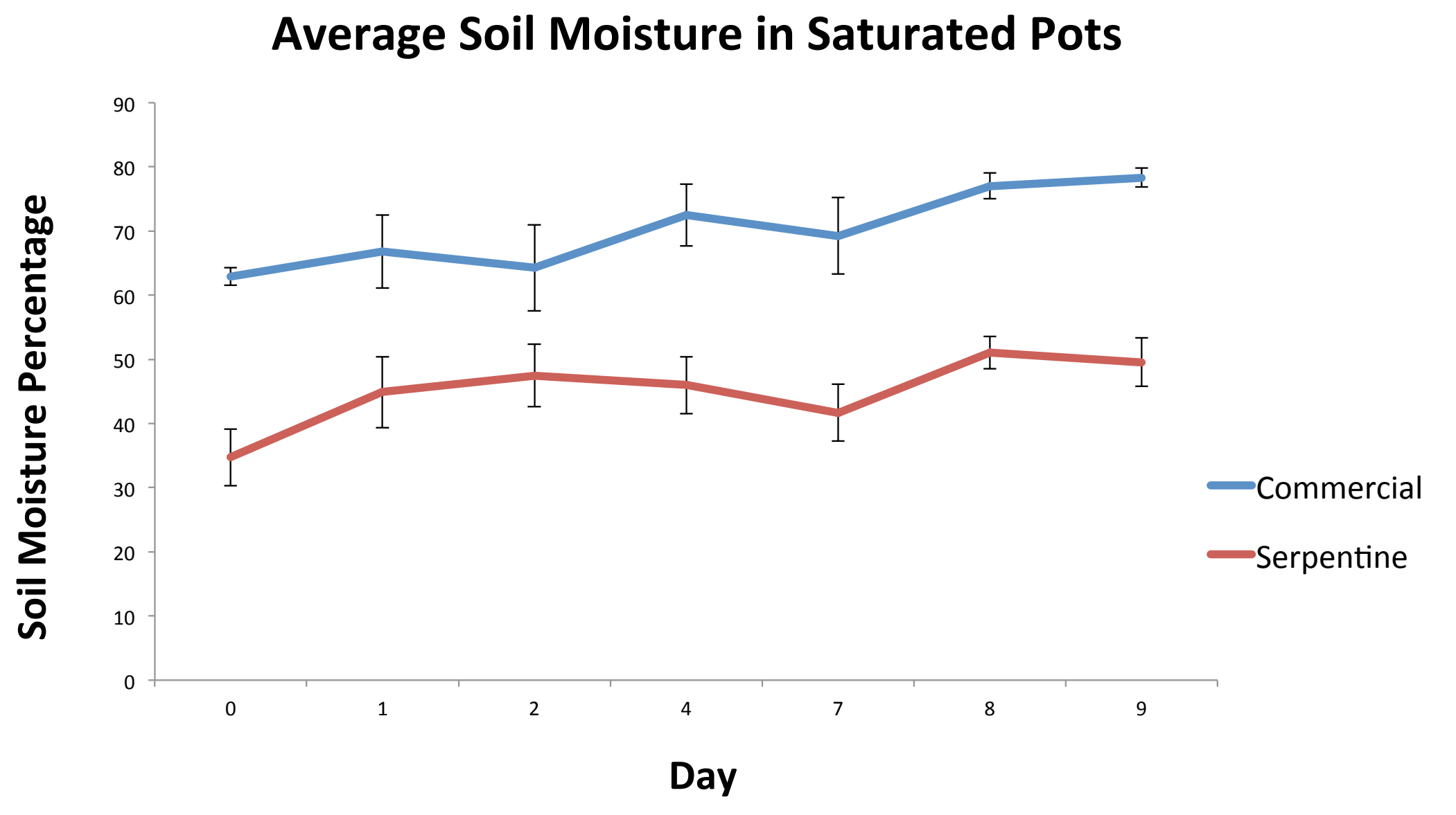


Figure 1: I took soil moisture measurements for both serpentine and commercial soils that were kept saturated over the period of time the data was collected (n=4; error bars represent standard error). Although serpentine soil seemed to show initially lower soil moisture levels on average, both soil types stayed relatively consistent in their moisture levels over time as water was continually added to all the pots.

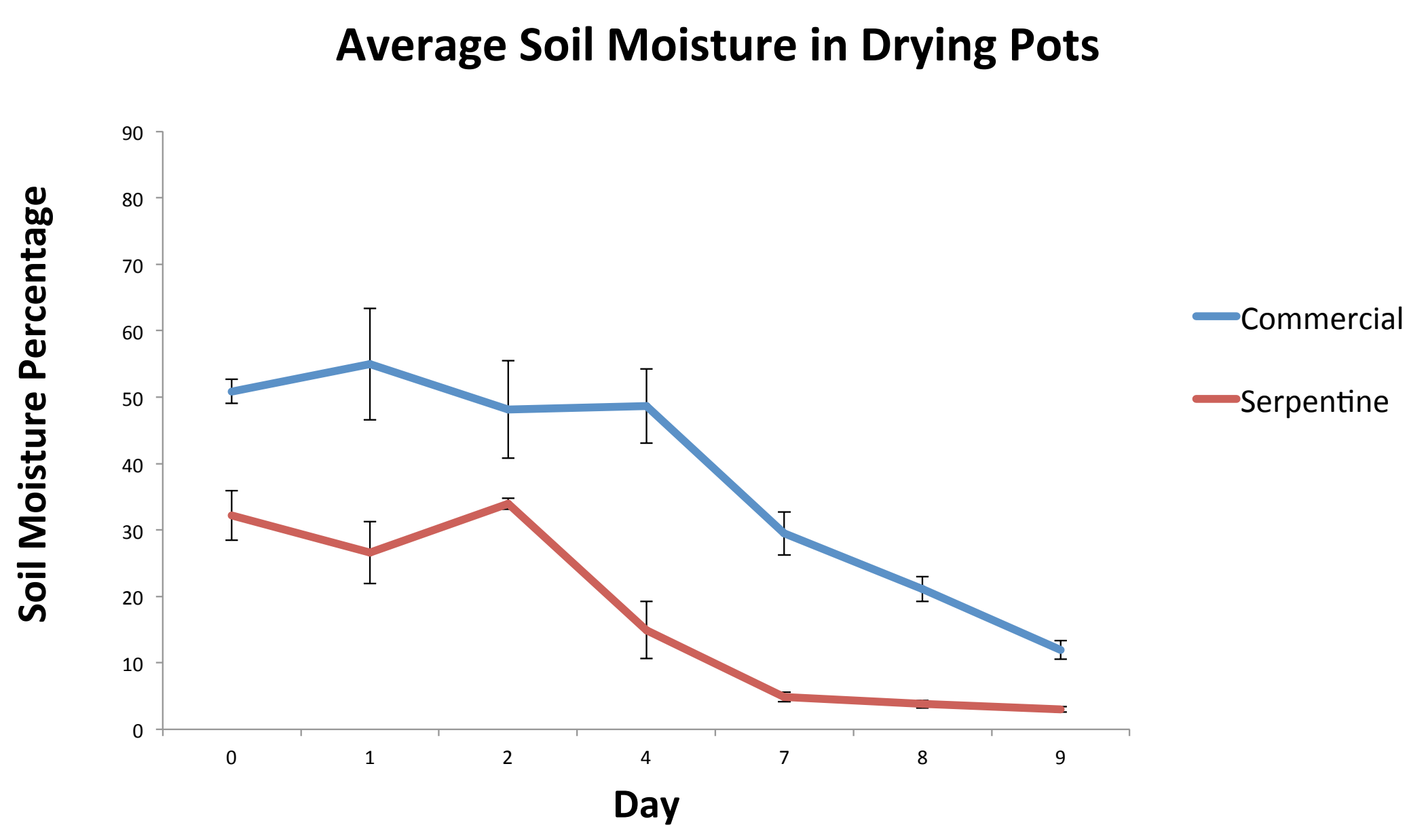


Figure 2: These pots started with saturated soil then were left to dry for several days while I monitored soil moisture. On average, soil moisture levels for serpentine soils started and maintained lower than commercial soils (n=4; error bars represent standard error). The biggest change in moisture levels between soils occurred at around Day 4, where the commercial soil moisture stayed relatively consistent from days 2-4, in contrast to the serpentine soil that had a steep drop in moisture in the same time frame.

Photosynthetic Analysis

I took photos of each pot and analyzed them using the program ImageJ to obtain each plant's surface area. I then took photos using a DIY Infrared camera with a blue filter to analyze plant health through the program Infragram, which generated an infrared plant analysis image. The image was further analyzed by using the Normalized Difference Vegetation Index (NDVI) scale to assess the areas of the plant that were performing high photosynthetic activity. A numerical range indicating good plant health was merged with ImageJ to give a proportion of leaf surface area illustrating high photosynthetic activity.

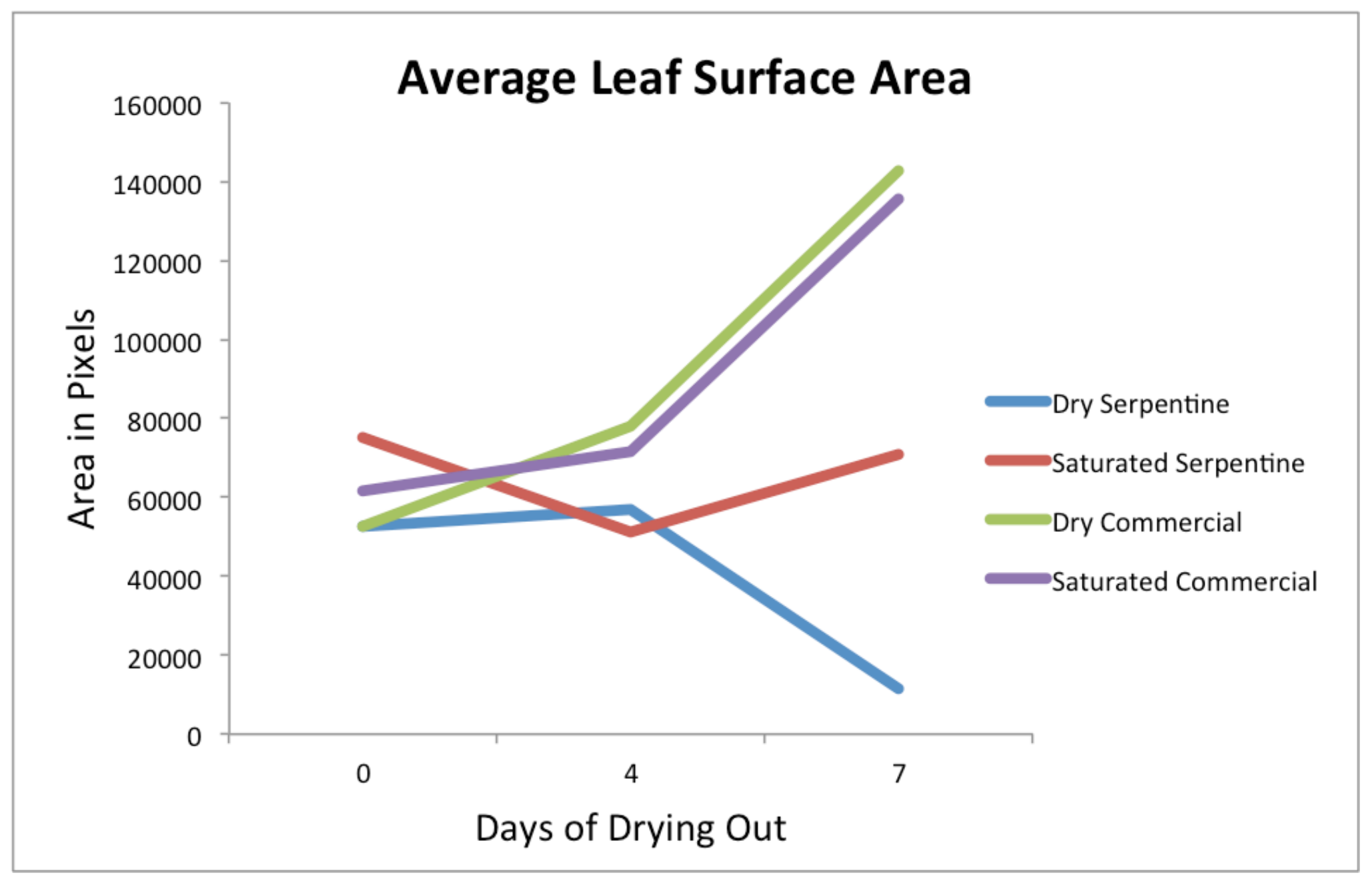
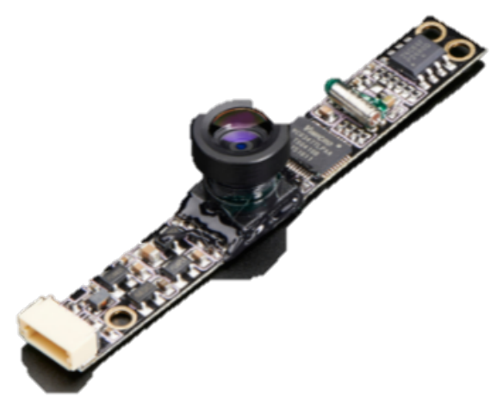


Figure 3: On average, all treatments had a relative steady leaf surface area from days 0-4 (n=4). Both the saturated and drying commercial soil treatments had a steep surface area increase from days 4-7. The saturated serpentine soil resulted in a fairly static leaf surface area over time, while the drying out serpentine had a steep decrease after day 4.



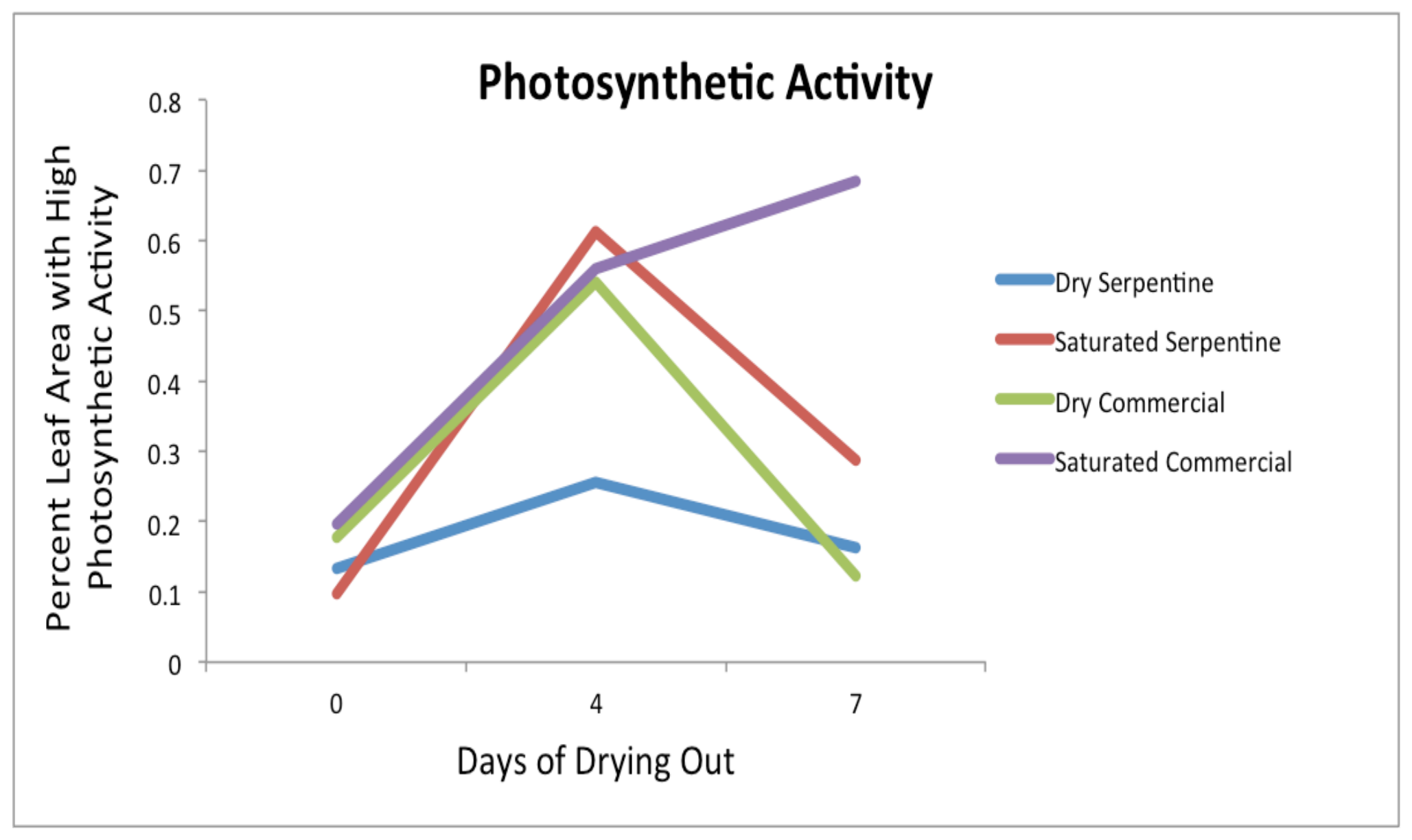
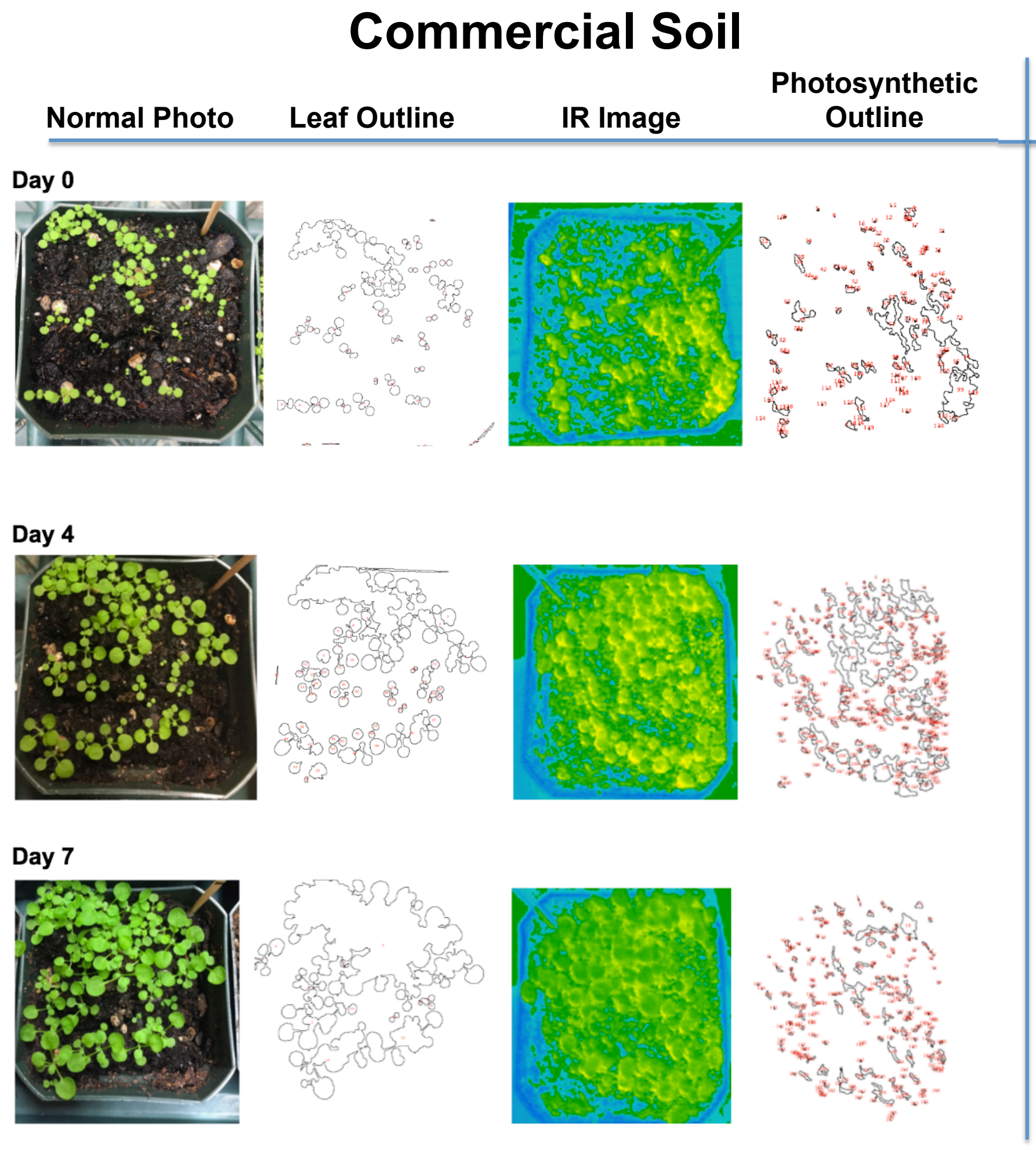


Figure 4: Areas of high NDVI were divided by the total leaf surface area to get a proportion of the plant with good plant health (n=4). The saturated commercial soil was the only treatment that had increased photosynthetic activity over the entire period of the study. The saturated serpentine and dry commercial soils had the most varying photosynthetic levels over the entire 7 days.



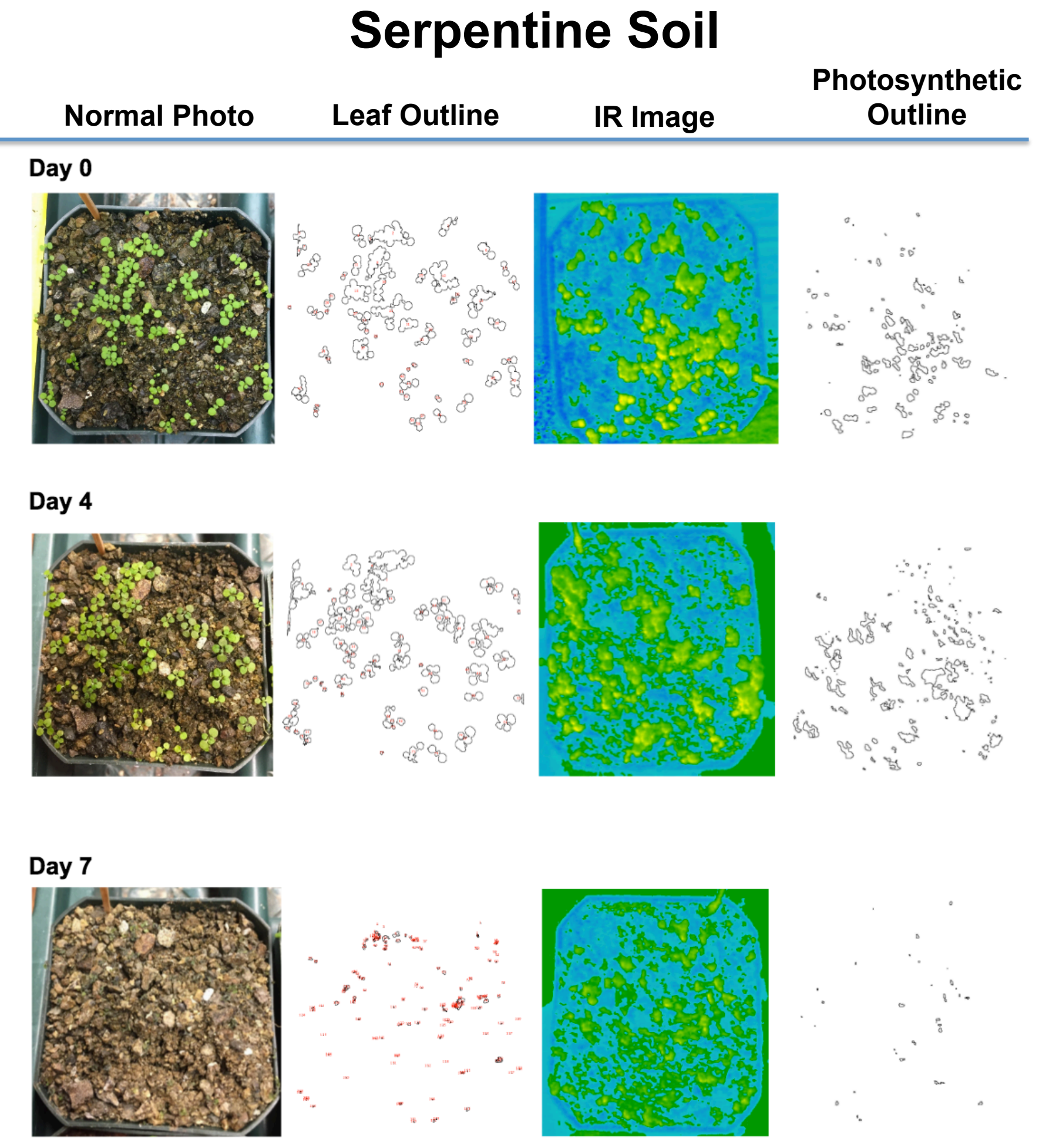
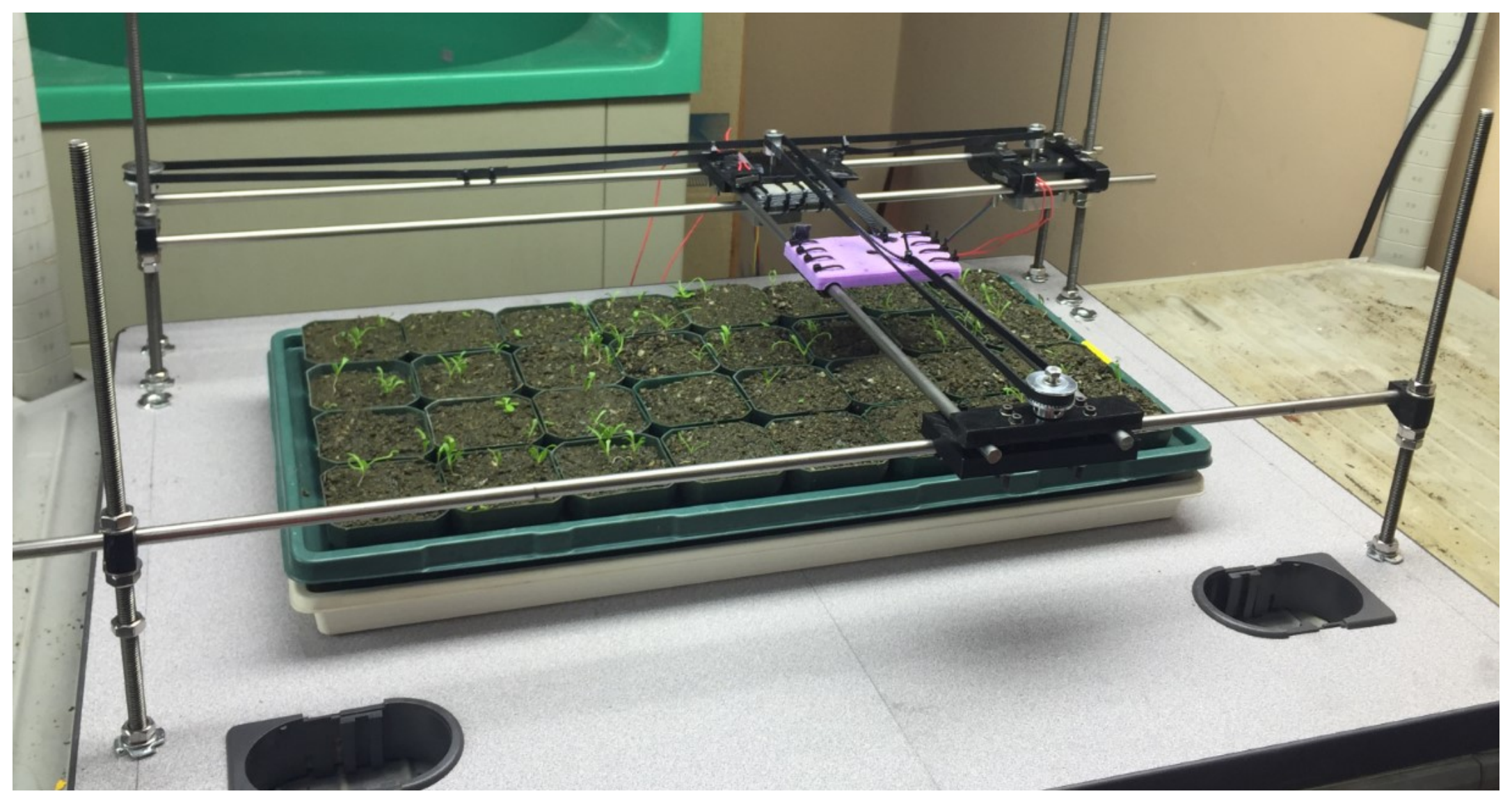


Figure 5: These are snapshots of just one of the four planted commercial pots that was left drying out for 7 days. The outline images were generated from ImageJ showing the surface area of seedlings. I analyzed data on each pot on the initial day of drying, 4 days of drying, and 7 days of drying. Although the collective leaf surface area of each pot continued to increase over time, the actual photosynthetic plant health was decreasing after day 4, which can be seen by the brightness of yellow peaking at day 4 and diminishing by day 7.

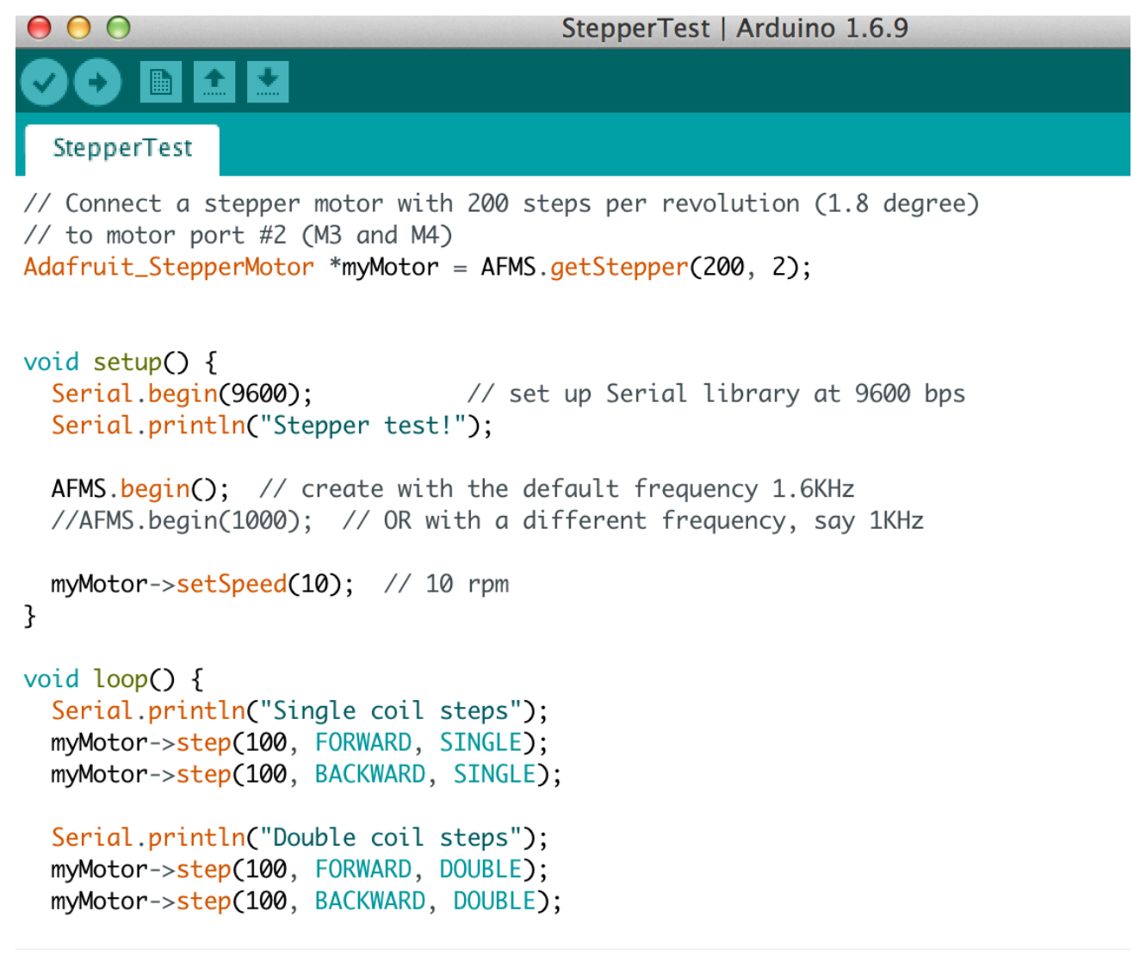
Figure 6: This set of data represents one pot from the drying serpentine soil treatment. The leaf surface area slowly declined within the first 4 days of drying, and was barely apparent by day 7 of drying. The plants were not showing photosynthetic activity to begin with since this species is non-adaptive to serpentine soil. The photosynthetic activity decreased over time as well with very low levels occurring by day 7 of drying.

Cartesian Robot

During the study, we created a Cartesian robot that can collect plant data over a grid of small pots in a lab setting. The robot's purpose is to collect specific data of interest to the user without having to manually take daily measurements. For example, an IR camera could take photos of each pot at a certain time of the day for several days.



We used Arduino programming software to create code and operate the robot. The code works to move two motors a specific number of steps in a repeating loop sequence to move the sensor of choice over each plant pot to collect individual data. Many parts of the robot were created using a 3D printer.



```
// Connect a stepper motor with 200 steps per revolution (1.8 degree)
// to motor port #2 (M3 and M4)
Adafruit_StepperMotor *myMotor = AFMS.getStepper(200, 2);


void setup() {
  Serial.begin(9600);           // set up Serial library at 9600 bps
  Serial.println("Stepper test!");

  AFMS.begin();  // create with the default frequency 1.6KHz
  //AFMS.begin(1000);  // OR with a different frequency, say 1KHz

  myMotor->setSpeed(10);  // 10 rpm
}

void loop() {
  Serial.println("Single coil steps");
  myMotor->step(100, FORWARD, SINGLE);
  myMotor->step(100, BACKWARD, SINGLE);

  Serial.println("Double coil steps");
  myMotor->step(100, FORWARD, DOUBLE);
  myMotor->step(100, BACKWARD, DOUBLE);
```

Conclusions

- We were able to successfully examine the effects of serpentine soil on a non-adapted plant species using Arduino.
- Serpentine soil dries out faster than commercial soil.
- Even when serpentine soil is kept saturated, it still produces photosynthetically less healthy plants than those growing in commercial soil.
- Inexpensive Arduino-based sensors are effective for soil moisture and photosynthetic analysis.

Although we haven't yet attached a specific sensor to the robot, a sensor can be placed to work as a camera, fan, moisture sensor, or any other sensor of interest based on the study. There would need to be more work done in both the software and hardware of the project to accomplish the task of enabling a working sensor onto the robot.

Acknowledgements

This material is based upon work supported by a grant from the S.D. Bechtel, Jr. Foundation and the California State University STEM Teacher Researcher Program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Foundation. Additional contributions were made by Brian Paavo through guidance and assistance with the Cartesian robot and Arduino coding.