AV Profit REAP25

Bijesh Mishra, Ph.D.

2024-12-11

Table of contents

NOTE: RUN “SUMULATION R25” BEFORE RUNNING THIS CODE FOR UPDATED INFORMATION.

Analysis in this file start by loading data saved after simulating tomato and strawberry AV profits. See simulation file for more details. The result tables I have here are quite big. Results are summarized in separate excel files.

1 Setting Up

1.1 Housekeeping

```
# #| echo: TRUE
rm(list = ls()) # Clean the environment.
options(
  warn=0, # Warnings. options(warn=-1) / options(warn=0)
  scipen=999 # No scientific notations.
  )
```

1.2 Load libraries

```
library(tidyverse, warn.conflicts = FALSE, quietly = TRUE)
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.0     v stringr   1.5.1
v ggplot2   3.5.1     v tibble    3.2.1
v lubridate 1.9.3     v tidyr     1.3.1
v purrr     1.0.2
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to becom
```

```
library(psych, warn.conflicts = FALSE, quietly = TRUE)
library(likert,  warn.conflicts = FALSE, quietly = TRUE)
library(mice,  warn.conflicts = FALSE, quietly = TRUE)
library(openxlsx2, warn.conflicts = FALSE, quietly = TRUE)
library(ggpubr, warn.conflicts = FALSE, quietly = TRUE)
library(gmodels,  warn.conflicts = FALSE, quietly = TRUE)
library(reshape2, warn.conflicts = FALSE, quietly = TRUE)
```

```r
library(arrow, warn.conflicts = FALSE, quietly = TRUE)
library(plot3D, warn.conflicts = FALSE, quietly = TRUE)
library(plotly, warn.conflicts = FALSE, quietly = TRUE)
library(lattice, warn.conflicts = FALSE, quietly = TRUE)
library(purrr, warn.conflicts = FALSE, quietly = TRUE)
library(furrr, warn.conflicts = FALSE, quietly = TRUE)
library(pheatmap, warn.conflicts = FALSE, quietly = TRUE)
library(grid, warn.conflicts = FALSE, quietly = TRUE)
library(data.table, warn.conflicts = FALSE, quietly = TRUE)
library(parallel, warn.conflicts = FALSE, quietly = TRUE)
```

2 Import data

Import necessary data.

2.1 Tomato AV

Parameters defining agrivoltaic systems:

- sprop = proportion of solar in agrivoltaic system (0 to 1 in 0.5 increment.) Length = 21.
- panels = number of solar panels. Length = 16. Some sprop have same number of panels.
- al_regs = four regions of Alabama. Northern, Central, Black Belt, Southern. Length = 4.
- array = Solar array; Sun tracking (Tracking) and non-tracking (Fixed). Length = 2.
- elecprc = electricity price (1 cents to 6 cents). Length = 6.
- height = clearance height of solar panels. 4.6 ft., 6.4 ft., and 8.2 ft. Length = 3.
- yldvar = crop yield variation (10% to 200%) = Length 21.
- yield = crop yield variation based on yldvar. (same as yldvar) = Length = 21.

Calculated results using above parameters:

- dc_kw = DC system size (kW) See PVWatts® Calculator.
- energy = total energy generated from solar system. See: PVWatts® Calculator.
- capex = AV system capex per kW. See: Capex Cost for AV table 1 and table 3.
- ttlcost = total solar system cost in AV. See: Capex Cost for AV table 1 and table 3.

- anncost = annualized total cost.
- moncost = monthly total cost.
- price = crop yield price per bucket.
- eprofit = profit from electricity.

Result of Interests:

- eannprof = annualized total profit from electricity.
- emonprof = monthly total profit from electricity.
- profit = profit from crops.
- tav_profit = total profit from solar and tomato.

```
tav_profit <- as.data.frame(
  read_feather(file = "Data/tav_profit R25.feather")
  )
dim(tav_profit)
```

```
[1] 814968     30
```

2.1.1 TAVP - Tomato Profit

- Profit at 100% crop yield at their respective price is subtracted from tav_profit.
- tavp_wocp = tav_profit - profit from 100% crop at their respective prices. This variable gives an idea where av profit stands in relation to crop profit. It helps to identify relative profitability of agrivoltaic system compared to crop only.

```
# Calculate the profit:
# Step 1: Filter the dataframe to get the unique profit values for each price when yldva
unique_profits <- unique(tav_profit[tav_profit$yldvar == 1,
                                    c("price", "profit")])

# Step 2: Create a lookup table for unique profits by price
profit_lookup <- setNames(unique_profits$profit,
                          unique_profits$price)

# Step 3: Create the new variable tavp_wocp by subtracting the unique profit from tav_pr
tav_profit$tavp_wocp <- mapply(function(
    tav_profit,
    price
```

```r
    ) {
  profit_to_subtract <- ifelse(
    price %in%
      names(profit_lookup),
    profit_lookup[as.character(price)], 0)
  return(tav_profit - profit_to_subtract)
}, tav_profit$tav_profit, tav_profit$price)
unique_profits # 7 Prices give 7 Profits at 100% Yield.
```

```
    price    profit
11     17  5539.383
32     18  6899.383
53     19  8259.383
74     20  9619.383
95     21 10979.383
116    22 12339.383
137    23 13699.383
```

```r
tav_profit[1:21,] # Sample data.
```

```
   sprop    al_regs array dc_kw panels energy elcprc elcrev height    capex
1      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
2      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
3      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
4      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
5      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
6      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
7      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
8      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
9      0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
10     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
11     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
12     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
13     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
14     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
15     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
16     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
17     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
18     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
19     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
20     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
21     0 Black Belt Fixed     0      0      0   0.01      0    4.6 1.593333
   landlease ttlcost inscst recredit reap annlzcost annoftotcost monthlycost
```

1	1000	0	0	0	0	0	0	0
2	1000	0	0	0	0	0	0	0
3	1000	0	0	0	0	0	0	0
4	1000	0	0	0	0	0	0	0
5	1000	0	0	0	0	0	0	0
6	1000	0	0	0	0	0	0	0
7	1000	0	0	0	0	0	0	0
8	1000	0	0	0	0	0	0	0
9	1000	0	0	0	0	0	0	0
10	1000	0	0	0	0	0	0	0
11	1000	0	0	0	0	0	0	0
12	1000	0	0	0	0	0	0	0
13	1000	0	0	0	0	0	0	0
14	1000	0	0	0	0	0	0	0
15	1000	0	0	0	0	0	0	0
16	1000	0	0	0	0	0	0	0
17	1000	0	0	0	0	0	0	0
18	1000	0	0	0	0	0	0	0
19	1000	0	0	0	0	0	0	0
20	1000	0	0	0	0	0	0	0
21	1000	0	0	0	0	0	0	0

	opex	taxcr	anncost	eannprof	eannprofworeap	eannprofwoincentives	yldvar	yield
1	0	0	0	0	0	0	2.0	2720
2	0	0	0	0	0	0	1.9	2584
3	0	0	0	0	0	0	1.8	2448
4	0	0	0	0	0	0	1.7	2312
5	0	0	0	0	0	0	1.6	2176
6	0	0	0	0	0	0	1.5	2040
7	0	0	0	0	0	0	1.4	1904
8	0	0	0	0	0	0	1.3	1768
9	0	0	0	0	0	0	1.2	1632
10	0	0	0	0	0	0	1.1	1496
11	0	0	0	0	0	0	1.0	1360
12	0	0	0	0	0	0	0.9	1224
13	0	0	0	0	0	0	0.8	1088
14	0	0	0	0	0	0	0.7	952
15	0	0	0	0	0	0	0.6	816
16	0	0	0	0	0	0	0.5	680
17	0	0	0	0	0	0	0.4	544
18	0	0	0	0	0	0	0.3	408
19	0	0	0	0	0	0	0.2	272
20	0	0	0	0	0	0	0.1	136
21	0	0	0	0	0	0	0.0	0

```
   price       profit  tav_profit tavp_ge_t tavp_wocp
1     17   21679.3826  21679.3826         0     16140
2     17   20065.3826  20065.3826         0     14526
3     17   18451.3826  18451.3826         0     12912
4     17   16837.3826  16837.3826         0     11298
5     17   15223.3826  15223.3826         0      9684
6     17   13609.3826  13609.3826         0      8070
7     17   11995.3826  11995.3826         0      6456
8     17   10381.3826  10381.3826         0      4842
9     17    8767.3826   8767.3826         0      3228
10    17    7153.3826   7153.3826         0      1614
11    17    5539.3826   5539.3826         1         0
12    17    3925.3826   3925.3826         0     -1614
13    17    2311.3826   2311.3826         0     -3228
14    17     697.3826    697.3826         0     -4842
15    17    -916.6174   -916.6174         0     -6456
16    17   -2530.6174  -2530.6174         0     -8070
17    17   -4144.6174  -4144.6174         0     -9684
18    17   -5758.6174  -5758.6174         0    -11298
19    17   -7372.6174  -7372.6174         0    -12912
20    17   -8986.6174  -8986.6174         0    -14526
21    17  -10600.6174 -10600.6174         0    -16140
```

```
rm(unique_profits); rm(profit_lookup)
```

2.1.2 TAVP GE Tomato

Tomato yield where tomato AV start becoming more profitable than tomato alone.

```
# Convert the data frame to a data.table for faster operations
setDT(tav_profit)

# Function to process each subset
process_subset <- function(subset) {
  subset <- subset[order(-tavp_wocp)]

  # Find the row where yield changes from positive to negative
  change_row <- which(diff(sign(subset$tavp_wocp)) == -2)[1]

  # Check if change_row is not NA
  if (!is.na(change_row)) {
    result_row <- subset[change_row, ]
```

```
    return(result_row)
  } else {
    return(NULL)
  }
}

# Split data by unique combinations of the filtering criteria
split_data <- split(tav_profit,
                    by = c("al_regs", "array", "sprop",
                           "elcprc", "price", "height"))

# Apply the process_subset function sequentially using lapply
results <- lapply(split_data, process_subset)

# Combine all results into a single data.table
tav_be_yld <- rbindlist(results,
                        use.names = TRUE,
                        fill = TRUE) %>%
  select(al_regs, array, sprop, panels, elcprc, price,
         height, profit, yldvar, yield, tav_profit, tavp_wocp)
dim(tav_be_yld)
```

```
[1] 32852    12
```

```
# Dimension and Clean up
rm(results); rm(split_data); rm(process_subset)
```

```
write_xlsx(x = tav_be_yld,
           file = "Results/TAV Tomato Breakeven Yield R25.xlsx",
           as_table = TRUE)
```

2.1.3 Tax Credit for TAV

How much money should be spent as REAP or tax credit to make AV as profitable as crop?

```
tcc_tav_tomato_r25 <- tav_profit %>%
  filter(yldvar == 1,
         elcprc == 0.04,
         price == 20,
         sprop >= 0.1
```

```r
        )
tcc_tav_tomato_r25[which.max(tcc_tav_tomato_r25$eannprofworeap),]
```

```
   sprop  al_regs    array dc_kw panels energy elcprc  elcrev height    capex
   <num>   <char>   <char> <num>  <num>  <num>  <num>   <num>  <num>    <num>
1:   0.1 Southern Tracking 28.25     59  47537   0.04 1901.48    4.6 1.733333
   landlease  ttlcost   inscst recredit     reap annlzcost annoftotcost
       <num>    <num>    <num>    <num>    <num>     <num>        <num>
1:      1000 55735.33 278.6767 313.7442 13928.96   3611.34     4782.678
   monthlycost     opex    taxcr  anncost eannprof eannprofworeap
         <num>    <num>    <num>    <num>    <num>          <num>
1:    159.1859 143.4803 1434.803 3754.821 -104.793       -1132.65
   eannprofwoincentives yldvar yield price   profit tav_profit tavp_ge_t
                  <num>  <num> <num> <num>    <num>      <num>     <num>
1:            -2881.198      1  1360    20 9619.383    9514.59         0
   tavp_wocp
       <num>
1:  -104.793
```

```r
cat("Minimum REAP Compensation to make TAV as profitable as Tomato: ",
    abs(max(tcc_tav_tomato_r25$eannprofworeap)) + 9619.38, fill = TRUE)
```

```
Minimum REAP Compensation to make TAV as profitable as Tomato:  10752.03
```

```r
tcc_tav_tomato_r25[which.min(tcc_tav_tomato_r25$eannprofworeap),]
```

```
   sprop  al_regs  array  dc_kw panels energy elcprc  elcrev height capex
   <num>   <char> <char>  <num>  <num>  <num>  <num>   <num>  <num> <num>
1:     1 Northern  Fixed 423.74    885 574020   0.04 22960.8    8.2  2.33
   landlease ttlcost   inscst recredit   reap annlzcost annoftotcost
       <num>   <num>    <num>    <num>  <num>     <num>        <num>
1:      1000 1123817 5619.086 3788.532 280856  72817.12     96435.34
   monthlycost    opex   taxcr  anncost   eannprof eannprofworeap
         <num>   <num>   <num>    <num>      <num>          <num>
1:     3209.74 2893.06 28930.6 75710.18 -20030.25      -40755.41
   eannprofwoincentives yldvar yield price   profit tav_profit tavp_ge_t
                  <num>  <num> <num> <num>    <num>      <num>     <num>
1:            -73474.54      1  1360    20 9619.383  -10410.86         0
   tavp_wocp
       <num>
1: -20030.25
```

```r
cat("Maximum REAP Compensation to make TAV as profitable as Tomato: ",
    abs(min(tcc_tav_tomato_r25$eannprofworeap)) + 9619.38, fill = TRUE)
```

```
Maximum REAP Compensation to make TAV as profitable as Tomato:  50374.79
```

2.2 Strawberry AV

See tomato for variable descriptions.

sbav_profit = total profit from solar and strawberry.

```r
sbav_profit <- as.data.frame(
  read_feather(file = "Data/sbav_profit R25.feather")
  )
dim(sbav_profit)
```

```
[1] 814968     30
```

2.2.1 SBAVP - Strawberry Profit

- Profit at 100% crop at their respective price is subtracted from sbav_profit.
- sbavp_wocp = sbav_profit - profit from 100% crop at their respective prices. This variable gives an idea where av profit stands in relation to crop profit. It helps to identify relative profitability of agrivoltaic system compared to crop only.

```r
# Calculate the profit:
# Step 1: Filter the dataframe to get the unique profit values for each price when yldva
unique_profits <- unique(sbav_profit[sbav_profit$yldvar == 1,
                                     c("price", "profit")])

# Step 2: Create a lookup table for unique profits by price
profit_lookup <- setNames(unique_profits$profit,
                          unique_profits$price)

# Step 3: Create the new variable sbavp_wocp by subtracting the unique profit from sqav_
sbav_profit$sbavp_wocp <- mapply(function(sbav_profit, price) {
  profit_to_subtract <- ifelse(price %in%
                                 names(profit_lookup),
                               profit_lookup[as.character(price)], 0)
  return(sbav_profit - profit_to_subtract)
```

```
}, sbav_profit$sbav_profit, sbav_profit$price)

unique_profits # 7 Prices give 7 Profits at 100% Yield.
```

```
    price    profit
11      3 -5049.345
32      4 -1974.345
53      5  1100.655
74      6  4175.655
95      7  7250.655
116     8 10325.655
137     9 13400.655
```

```
rm(unique_profits); rm(profit_lookup)
```

2.2.2 SBAVP GE Strawberry Profit

Strawberry yield where strawberry AV profit start becoming more profitable than strawberry alone.

```
# Convert the data frame to a data.table for faster operations
setDT(sbav_profit)

# Function to process each subset
process_subset <- function(subset) {
  subset <- subset[order(-sbavp_wocp)]

  # Find the row where yield changes from positive to negative
  change_row <- which(diff(sign(subset$sbavp_wocp)) == -2)[1]

  # Check if change_row is not NA
  if (!is.na(change_row)) {
    result_row <- subset[change_row, ]
    return(result_row)
  } else {
    return(NULL)
  }
}

# Split data by unique combinations of the filtering criteria
split_data <- split(sbav_profit,
```

```
                    by = c("al_regs", "array", "sprop",
                           "elcprc", "price", "height"))

# Apply the process_subset function sequentially using lapply
results <- lapply(split_data, process_subset)

# Combine all results into a single data.table
sbav_be_yld <- rbindlist(results,
                         use.names = TRUE,
                         fill = TRUE) %>%
  select(al_regs, array, sprop, panels, elcprc, price,
         height, profit, yldvar, yield, sbav_profit, sbavp_wocp)

# Clean up
rm(results); rm(split_data); rm(process_subset)
```

```
write_xlsx(x = sbav_be_yld,
           file = "Results/SBAV Strawberry Breakeven Yield R25.xlsx",
           as.table = TRUE)
```

```
Warning in standardize_case_names(params, arguments = arguments, return =
TRUE): unused arguments (as.table)

Warning in standardize_case_names(..., arguments = arguments): unused arguments
(as.table)
```

```
dim(sbav_be_yld)
```

```
[1] 28749    12
```

2.2.3 Tax Credit for SBAV

How much money should be spent as REAP or tax credit to make AV as profitable as crop?

```
tcc_sbav_stberry_r25 <- sbav_profit %>%
  filter(yldvar == 1,
         elcprc == 0.04,
         price == 6,
         sprop >= 0.1
         )
tcc_sbav_stberry_r25[which.max(tcc_sbav_stberry_r25$eannprofworeap)]
```

```
   sprop   al_regs    array dc_kw panels energy elcprc  elcrev height    capex
   <num>    <char>   <char> <num>  <num>  <num>  <num>   <num>  <num>    <num>
1:   0.1 Southern Tracking 28.25     59  47537   0.04 1901.48    4.6 1.733333
   landlease  ttlcost   inscst recredit     reap annlzcost annoftotcost
       <num>    <num>    <num>    <num>    <num>     <num>        <num>
1:      1000 55735.33 278.6767 313.7442 13928.96   3611.34     4782.678
   monthlycost     opex    taxcr  anncost eannprof eannprofworeap
         <num>    <num>    <num>    <num>    <num>          <num>
1:    159.1859 143.4803 1434.803 3754.821 -104.793       -1132.65
   eannprofwoincentives yldvar yield price   profit sbav_profit sbavp_ge_sb
                  <num>  <num> <num> <num>    <num>       <num>       <num>
1:            -2881.198      1  3075     6 4175.655    4070.862           0
   sbavp_wocp
        <num>
1:   -104.793
```

```
cat("Minimum REAP Compensation to make SBAV profitable as Strawberry: ",
    abs(max(tcc_sbav_stberry_r25$eannprofworeap)) + 1715.96, fill = TRUE)
```

```
Minimum REAP Compensation to make SBAV profitable as Strawberry:  2848.61
```

```
tcc_sbav_stberry_r25[which.min(tcc_sbav_stberry_r25$eannprofworeap)]
```

```
   sprop   al_regs  array  dc_kw panels energy elcprc  elcrev height capex
   <num>    <char> <char>  <num>  <num>  <num>  <num>   <num>  <num> <num>
1:     1 Northern  Fixed 423.74    885 574020   0.04 22960.8    8.2  2.33
   landlease ttlcost   inscst recredit   reap annlzcost annoftotcost
       <num>   <num>    <num>    <num>  <num>     <num>        <num>
1:      1000 1123817 5619.086 3788.532 280856  72817.12     96435.34
   monthlycost    opex   taxcr   anncost   eannprof eannprofworeap
         <num>   <num>   <num>     <num>      <num>          <num>
1:     3209.74 2893.06 28930.6 75710.18 -20030.25      -40755.41
   eannprofwoincentives yldvar yield price   profit sbav_profit sbavp_ge_sb
                  <num>  <num> <num> <num>    <num>       <num>       <num>
1:            -73474.54      1  3075     6 4175.655   -15854.59           0
   sbavp_wocp
        <num>
1:  -20030.25
```

```r
cat("Maximum REAP Compensation to make SBAV profitable as Strawberry: ",
    abs(min(tcc_sbav_stberry_r25$eannprofworeap)) + 1715.96, fill = TRUE)
```

```
Maximum REAP Compensation to make SBAV profitable as Strawberry:  42471.37
```

3 Tomato AV Results

3.1 TAV Profit Crosstab

```r
sprop <- c(0.10, 0.20, 0.30, 0.40, 0.50,
          0.60, 0.70, 0.80, 0.90, 1.00)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
yldvar <- c(0.5, 1, 1.5)
al_regs <- c("Northern", "Central",
             "Black Belt", "Southern") # Regions AL
price <- c(17, 20, 23) # Crop Price
elcprc <- c(0.04) # Electricity Price

# Define the required columns
required_columns <- c("sprop", "array", "height",
                      "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in tav_profit
missing_columns <- setdiff(required_columns,
                           names(tav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in tav_profit: ",
       paste(missing_columns,
             collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3], " ", x[2], " ", x[1]))

# Generate row names using reversed order of expand.grid (without elcprc)
row_names <- apply(expand.grid(price, yldvar, al_regs), 1,
                   function(x) paste0(x[3], " ", x[2], " ", x[1]))
```

```r
# Create an empty matrix to store the results
result_matrix <- matrix(NA,
                        nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Dataframe with all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tav_profit to get tav_profit values for each combination
merged_data <- merge(param_combinations,
                     tav_profit,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data, fill result_matrix with
# reversed column/row names (excluding elcprc in row_name)
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1], " ", x[2], " ", x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price")], 1,
  function(x) paste0(x[1], " ", x[2], " ", x[3]))


# Fill the matrix with tav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[merged_data$row_name == row_condition, ]

  # Ensure that there are valid matches for col_name before assignment
  col_indices <- match(row_data$col_name,
                       colnames(result_matrix))
  valid_indices <- which(!is.na(col_indices))
```

```r
  if (length(valid_indices) > 0) {
    result_matrix[i, col_indices[valid_indices]] <- round(row_data$tav_profit[valid_indices]
  }
}

ct_tav_pft <- as.data.frame(result_matrix) # Table in Excel.
# Display the result matrix
rm(result_matrix); rm(sprop); rm(array); rm(height);
rm(elcprc); rm(price); rm(yldvar); rm(al_regs)
```

```r
write_xlsx(x = ct_tav_pft %>%
  dplyr::mutate(Row_Names = rownames(ct_tav_pft)) %>%
  dplyr::select(Row_Names, everything()),
           file = "Results/Profit Ctab TAV R25.xlsx",
           as_table = TRUE)
dim(ct_tav_pft)
```

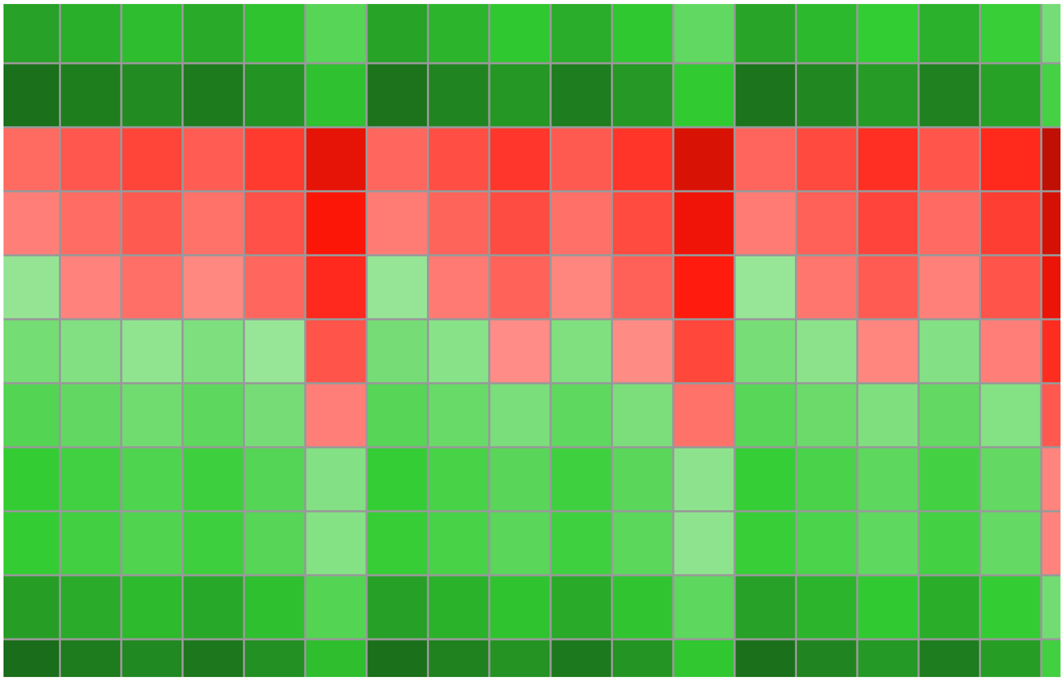
```
[1] 36 60
```

3.2 TAV Profit HeatMap

- Heatmap of 324*30 dimension matrix
- Tomato profit.

```r
# Calculate color count based on unique values, excluding zero
colorcount <- length(unique(as.vector(as.matrix(ct_tav_pft[-1]))))

# Define custom breaks to ensure zero is distinctly marked
# Calculate min and max values to define the range
min_val <- min(ct_tav_pft, na.rm = TRUE)
max_val <- max(ct_tav_pft, na.rm = TRUE)

# Create breaks that ensure zero is in the middle
breaks <- seq(min_val, max_val, length.out = colorcount)

# Separate color palettes for negative and positive values
# Negative values: Shades of red
neg_colors <- colorRampPalette(c("#890800",
                                 "#FF1709",
                                 "#FF8F89"))(sum(breaks < 0))
```

```r
# Define the color for zero separately
zero_color <- "#FF8F89"

# Positive values: Shades of green
pos_colors <- colorRampPalette(c("#99E699",
                                 "#32CD32",
                                 "#196719"))(sum(breaks > 0))

# Combine negative colors, zero, and positive colors
custom_colors <- c(neg_colors,
                   zero_color,
                   pos_colors)

# Generate heatmap with the custom color scheme
heatmap_plot <- pheatmap(
  (ct_tav_pft),
  clustering_distance_rows = "euclidean",
  clustering_distance_cols = "euclidean",
  clustering_method = "complete",
  angle_col = 90,
  na_col = "white",
  color = custom_colors,
  breaks = breaks,
  cutree_rows = 5,
  cutree_cols = 4,
  cluster_rows = FALSE,
  cluster_cols = FALSE,
  show_rownames = TRUE,
  show_colnames = TRUE,
  display_numbers = FALSE,
  fontsize_number = 5,
  number_color = "black",
  number_format = "%.0f",
  cellheight = 24,
  cellwidth = 23,
  fontsize = 18,
  fontsize_row = 22,
  fontsize_col = 22
)
```



```
ggsave(heatmap_plot,
       height = 18,
       width = 24,
       units = "in",
       limitsize = FALSE,
       file = paste0("Plots/TAV Profits CTab R25", ".png"))
#rm(colorcount); rm(heatmap_plot)
```

```
# Calculate color count based on unique values, excluding zero
colorcount <- length(unique(as.vector(as.matrix(ct_tav_pft[-1]))))

# Define custom breaks to ensure zero is distinctly marked
# Calculate min and max values to define the range
min_val <- min(ct_tav_pft, na.rm = TRUE)
max_val <- max(ct_tav_pft, na.rm = TRUE)

# Create breaks that ensure zero is in the middle
breaks <- seq(min_val, max_val, length.out = colorcount)

# Separate color palettes for negative and positive values
# Negative values: Shades of red
neg_colors <- colorRampPalette(c("#890800",
                                 "#FF1709",
```

```
                                  "#FF8F89"))(sum(breaks < 0))

# Define the color for zero separately
zero_color <- "#FF8F89"

# Positive values: Shades of green
pos_colors <- colorRampPalette(c("#99E699",
                                  "#32CD32",
                                  "#196719"))(sum(breaks > 0))

# Combine negative colors, zero, and positive colors
custom_colors <- c(neg_colors,
                   zero_color,
                   pos_colors)

# Generate heatmap with the custom color scheme
heatmap_plot <- pheatmap(
  (ct_tav_pft),
  clustering_distance_rows = "euclidean",
  clustering_distance_cols = "euclidean",
  clustering_method = "complete",
  angle_col = 90,
  na_col = "white",
  color = custom_colors,
  breaks = breaks,
  cutree_rows = 5,
  cutree_cols = 4,
  cluster_rows = FALSE,
  cluster_cols = FALSE,
  show_rownames = TRUE,
  show_colnames = TRUE,
  display_numbers = TRUE,
  fontsize_number = 5,
  number_color = "black",
  number_format = "%.0f",
  cellheight = 24,
  cellwidth = 23,
  fontsize = 18,
  fontsize_row = 22,
  fontsize_col = 22
)
```


```
ggsave(heatmap_plot,
       height = 18,
       width = 24,
       units = "in",
       limitsize = FALSE,
       file = paste0("Plots/TAV Profits CTab R25 Values", ".png"))
#rm(colorcount); rm(heatmap_plot)
```

3.3 TAV Profit Manuscript

```
# Define the values for each variable
sprop <- c(0, 0.25, 0.50, 0.75, 1.00)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
yldvar <- c(1) # Yield Variability
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(20) # Crop Price
elcprc <- c(0.04) # Electricity Price

# Define the required columns
required_columns <- c("sprop", "array", "height",
```

```r
                      "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in tav_profit
missing_columns <- setdiff(required_columns,
                           names(tav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in tav_profit: ",
       paste(missing_columns,
             collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, sprop), 1,
                   function(x) paste0(x[2], x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               yldvar,
                               al_regs,
                               array), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA,
                        nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tav_profit to get tav_profit values for each combination
merged_data <- merge(param_combinations,
```

```r
                     tav_profit,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data to fill result_matrix with
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "height")], 1,
  function(x) paste0(x[1], x[2]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price",
                  "elcprc", "array")], 1,
  function(x) paste0(
                     x[4],
                     x[3],
                     x[2],
                     x[1],
                     x[5]))

# Fill the matrix with tav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$tav_profit, 0)
  }
}
tav_prof_man <- as.data.frame(result_matrix) # Table in Excel.
# Display the result matrix
tav_prof_man
```

```
                          04.6 06.4 08.2 0.254.6 0.256.4 0.258.2 0.54.6 0.56.4
0.04201NorthernFixed      9619 9619 9619    8572    7542    5614   7174   4769
0.04201CentralFixed       9619 9619 9619    8766    7736    5808   7626   5221
0.04201Black BeltFixed    9619 9619 9619    8893    7863    5935   7921   5517
0.04201SouthernFixed      9619 9619 9619    8939    7909    5981   8029   5624
0.04201NorthernTracking   9619 9619 9619    8782    8026    7270   7665   5900
```

```
0.04201CentralTracking    9619 9619 9619     9073     8316     7560    8342    6577
0.04201Black BeltTracking 9619 9619 9619     9216     8460     7703    8676    6911
0.04201SouthernTracking   9619 9619 9619     9304     8548     7792    8882    7118
                          0.58.2 0.754.6 0.756.4 0.758.2 14.6 16.4   18.2
0.04201NorthernFixed         272     5777     1998     -5070 4379 -774 -10411
0.04201CentralFixed          724     6487     2709     -4359 5349  196  -9441
0.04201Black BeltFixed      1019     6951     3173     -3895 5981  828  -8809
0.04201SouthernFixed        1127     7120     3341     -3726 6212 1059  -8578
0.04201NorthernTracking     4135     6547     3774      1002 5430 1649  -2132
0.04201CentralTracking      4813     7612     4839      2066 6882 3100   -681
0.04201Black BeltTracking   5147     8137     5364      2591 7597 3816     35
0.04201SouthernTracking     5353     8461     5688      2915 8039 4258    477
```

```r
write_xlsx(x = tav_prof_man %>%
  dplyr::mutate(Row_Names = rownames(tav_prof_man)) %>%
  dplyr::select(Row_Names, everything()),
           file = "Results/Profit TAV Manuscript R25.xlsx",
           as_table = TRUE)
# Display the result matrix
rm(result_matrix); rm(sprop); rm(array); rm(height);
rm(elcprc); rm(price); rm(yldvar); rm(al_regs)
```

3.4 TAVP - Tomato Profit CrossTab

- Heatmap of 324*30 dimension matrix.
- See tav_profit for variable naming convention.

```r
# Define the values for each variable
sprop <- c(0, 0.05, 0.10, 0.15, 0.20, 0.25,
          0.30, 0.35, 0.40, 0.45, 0.50,
          0.55, 0.60, 0.65, 0.70, 0.75,
          0.80, 0.85, 0.90, 0.95, 1.00)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
yldvar <- c(0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90,
            1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60, 1.70, 1.80,
            1.90, 2.00)
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(17, 18, 19, 20, 21, 22, 23) # Crop Price
elcprc <- c(0.03, 0.04, 0.05) # Electricity Price
```

```r
# Define the required columns
required_columns <- c("sprop", "array", "height",
                     "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in tav_profit
missing_columns <- setdiff(required_columns,
                          names(tav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in tavp_wocp: ",
       paste(missing_columns, collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3], x[2], x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               yldvar,
                               al_regs), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA, nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tav_profit to get tav_profit values
merged_data <- merge(param_combinations,
                     tav_profit,
```

```r
                      by = required_columns,
                      all.x = TRUE)

# Reshape merged_data to fill result_matrix with
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1], x[2], x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price", "elcprc")], 1,
  function(x) paste0(x[4],
                      x[3],
                      x[2],
                      x[1]))

# Fill the matrix with tav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$tavp_wocp, 2)
  }
}
ct_tavp_wocp <- as.data.frame(result_matrix) # Table in Excel.
dim(ct_tavp_wocp);rm(result_matrix)
```

```
[1] 1764  126
```

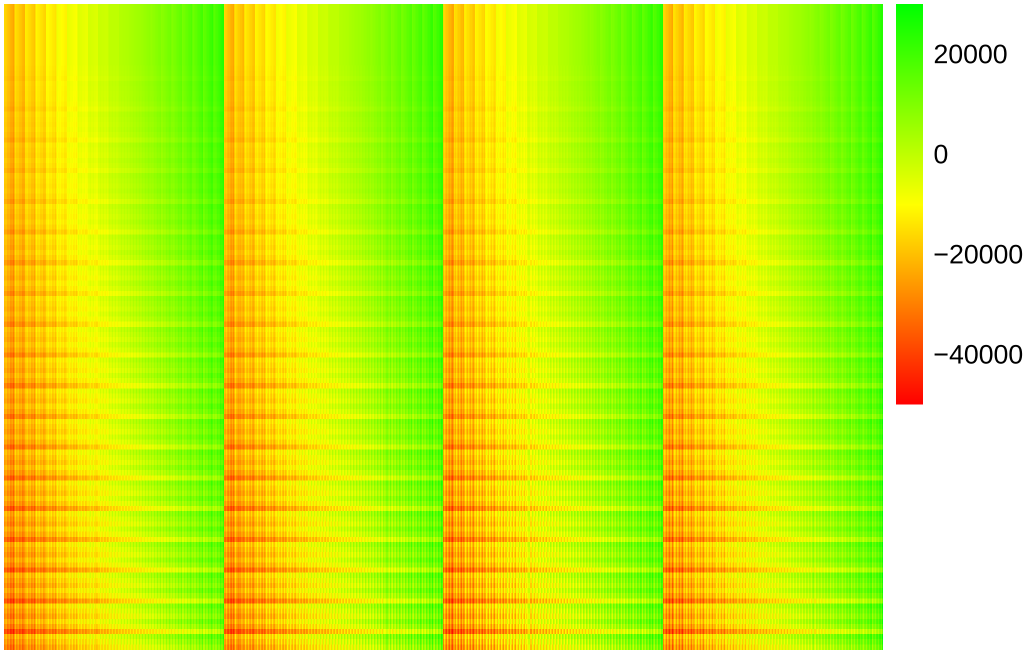
```r
write.csv(as.data.frame(ct_tavp_wocp),
          row.names = TRUE,
          file = "Results/ct_tavp_wocp R25.csv")
```

3.5 TAVP - Tomato Profit HeatMap

```r
colorcount = length(unique(as.vector(as.matrix(ct_tavp_wocp[-1]))))
colorcount
```

```
[1] 150080
```

```r
heatmap_plot <- pheatmap(t(ct_tavp_wocp),
                         #clustering_distance_rows = "correlation",
                         clustering_distance_rows = "euclidean",
                         clustering_distance_cols = "euclidean",
                         clustering_method = "complete",
                         color = colorRampPalette(c("red",
                                                    "yellow",
                                                    "green"))(colorcount),
                         #cutree_rows = 5,
                         #cutree_cols = 4,
                         cutree_rows = 5,
                         cutree_cols = 4,
                         cluster_rows = FALSE,
                         cluster_cols = FALSE,
                         show_rownames = FALSE,
                         show_colnames = FALSE,
                         display_numbers = FALSE,
                         number_format = "%.2f",
                         #cellheight = 3,
                         #cellwidth = 3
                         )
```




```
ggsave(heatmap_plot,
       height = 8,
       width = 12,
       units = "in",
       file = paste0("Plots/gp_tavp_wocp R25", ".png"))
rm(heatmap_plot); rm(colorcount)
```

3.6 TAV Breakeven Yield Crosstab

```
# Define the values for each variable
sprop <- c(0.05, 0.25, 0.50, 0.75, 0.80, 0.85, 0.90, 1)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(17, 20, 23) # Crop Price
elcprc <- c(0.02, 0.03, 0.04) # Electricity Price
yldvar <- c(1)
# Define the required columns
required_columns <- c("sprop", "array", "height",
                      "al_regs", "price", "elcprc")
```

```r
# Check if the columns exist in tav_profit
missing_columns <- setdiff(required_columns,
                           names(tav_be_yld))
if (length(missing_columns) > 0) {
  stop("Missing columns in tavp_be_yld: ",
       paste(missing_columns, collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3] , x[2] , x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               #yldvar,
                               al_regs), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA, nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  #yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tav_be_yld to get tav_be_yld values for each combination
merged_data <- merge(param_combinations,
                     tav_be_yld,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data to fill result_matrix with
```

```r
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1], x[2], x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "price", "elcprc")], 1,
  function(x) paste0(x[3],
                     x[2],
                     x[1]))

# Fill the matrix with tav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$yield, 0)
  }
}
ct_tav_be_yld <- as.data.frame(result_matrix) # Table in Excel.
dim(ct_tav_be_yld); rm(result_matrix)
```

```
[1] 36 48
```

```r
write.csv(as.data.frame(ct_tav_be_yld),
          row.names = TRUE,
          file = "Results/ct_tav_be_yld R25.csv")
```

3.7 TAV Breakeven Yield Heatmap

```r
uniquevalue = unique(as.vector(as.matrix(ct_tav_be_yld[-1])))
colorcount = length(unique(as.vector(as.matrix(ct_tav_be_yld[-1]))))
heatmap_plot <- pheatmap((ct_tav_be_yld),
                         #clustering_distance_rows = "correlation",
                         clustering_distance_rows = "euclidean",
```

```
                    clustering_distance_cols = "euclidean",
                    clustering_method = "complete",
                    angle_col = 90,
                    na_col = "white",
                    color = colorRampPalette(
                      c("green", "yellow","red")
                      )(colorcount),
                    cellheight = 13,
                    cellwidth = 14,
                    fontsize = 12,
                    fontsize_row = 12,
                    fontsize_col = 12,
                    number_color = "white",
                    fontsize_number = 5,
                    cluster_rows = FALSE,
                    cluster_cols = FALSE,
                    show_rownames = TRUE,
                    show_colnames = TRUE,
                    display_numbers = TRUE,
                    number_format = "%.0f"
                    #legend_breaks = uniquevalue
                    )
```

```
ggsave(heatmap_plot,
       height = 8,
       width = 12,
       units = "in",
       file = paste0("Plots/gp_tav_be_yld R25", ".png"))
rm(heatmap_plot); rm(colorcount); rm(uniquevalue)
```

3.8 Plot Tomato Profits by Panels

You can see plot breakdown based on yield variation, crop price, and electricity price. You can see variation for all solar proportion in one facet of the chart. Each facet of the chart contain av profit three heights of solar panels, four regions of AL, two array types.

```
combinations <- expand.grid(
  yldvar = c(0, 0.1, 0.3, 0.5, 0.7, 1, 1.20, 1.5, 1.80, 2), # Yield
  price = c(17, 20, 23), # Tomato price
  elcprc = c(0.03, 0.04, 0.05) #Electricity price
)

# Iterate over the combinations and create the plots
for (combo in seq_len(nrow(combinations))) {
  filtered_data <- tav_profit %>%
    filter(
      yldvar == combinations$yldvar[combo],
      price == combinations$price[combo],
      elcprc == combinations$elcprc[combo]
    )
  # If by panel, put panels below in color and group.
  tav_sp_plot <- ggplot(data = filtered_data,
                        mapping = aes(x = al_regs,
                                      y = tav_profit,
                                      color = factor(panels),
                                      group = factor(panels))) +
    geom_line() +
    geom_point() +
    facet_grid(height ~ array,
               labeller = as_labeller(
                 c(
                   "4.6" = "4.6 ft. Height",
                   "6.4" = "6.4 ft. Height",
                   "8.2" = "8.2 ft. Height",
```

```
                   Tracking = "Single Axis Rotation",
                   Fixed = "Fixed Open Rack"
                   ))) +
    guides(color = guide_legend(ncol = 1,
                                reverse = TRUE)) +
    scale_x_discrete(limits = c("Northern", "Central",
                                "Black Belt", "Southern"),
                     labels = c("North", "Center",
                                "B Belt", "South")) +
    guides(color = guide_legend(ncol = 2,
                                reverse = TRUE)) +
    labs(x = "Regions of Alabama",
         y = "Profit ($) from Tomato Agrivoltaic System",
         color = "Number of Solar \n Panels per Acre",
         title = (list(combinations[combo,]))
         ) +
    theme(strip.background = element_blank())

  # Add horizontal line at y = 0 if y has both positive and negative values
  if (min(filtered_data$tav_profit) < 0 &
      max(filtered_data$tav_profit) > 0) {
    tav_sp_plot <- tav_sp_plot +
      geom_hline(yintercept = 0,
                 linewidth = 0.30,
                 linetype = "dashed",
                 color = "black")
  }
  print(combinations[combo,])
  print(tav_sp_plot)
  ggsave(file = paste0("Plots/tav_sp_R25", combo, ".png"))
  #break
}
```

3.9 Plot Tomato Profits by Yields

You can see plot breakdown based on solar proportion, crop price, and electricity price. You can see variation for all crop yield variation in one facet of the chart. Each facet of the chart contain av profit three heights of solar panels, four regions of AL, two array types.

```
combinations <- expand.grid(
  sprop = c(0, 0.25, 0.50, 0.75, 1.00), # Solar proportion
```

```r
  price = c(17, 20, 23), # Tomato price
  elcprc = c(0.03, 0.04, 0.05) #Electricity price
)
# Iterate over the combinations and create the plots
for (combo in seq_len(nrow(combinations))) {
  filtered_data <- tav_profit %>%
    filter(
      sprop == combinations$sprop[combo],
      price == combinations$price[combo],
      elcprc == combinations$elcprc[combo]
    )
  # If by yield, put yield below in color and group.
  tav_yv_plot <- ggplot(data = filtered_data,
                        mapping = aes(x = al_regs,
                                      y = tav_profit,
                                      color = factor(yield),
                                      group = factor(yield))) +
    geom_line() +
    geom_point() +
    facet_grid(height ~ array,
               labeller = as_labeller(
                 c(
                   "4.6" = "4.6 ft. Height",
                   "6.4" = "6.4 ft. Height",
                   "8.2" = "8.2 ft. Height",
                   Tracking = "Single Axis Rotation",
                   Fixed = "Fixed Open Rack"
                   ))) +
    guides(color = guide_legend(ncol = 1,
                                reverse = TRUE)) +
    scale_x_discrete(limits = c("Northern", "Central",
                                "Black Belt", "Southern"),
                     labels = c("North", "Center",
                                "B Belt", "South")) +
    guides(color = guide_legend(ncol = 2,
                                reverse = TRUE)) +
    labs(x = "Regions of Alabama",
         y = "Profit ($) from Tomato Agrivoltaic System",
         color = "Tomato Yield \n (25 Lb Buckets)",
         title = (list(combinations[combo,]))
         ) +
    theme(strip.background = element_blank())
```

```r
  # Add horizontal line at y = 0 if y has both positive and negative values
  if (min(filtered_data$tav_profit) < 0 &
      max(filtered_data$tav_profit) > 0) {
    tav_yv_plot <- tav_yv_plot +
      geom_hline(yintercept = 0,
                 linewidth = 0.30,
                 linetype = "dashed",
                 color = "black")
  }
  print(combinations[combo,])
  print(tav_yv_plot)
  ggsave(file = paste0("Plots/tav_yv_R25", combo, ".png"))
  #break
}
```

4 Strawberry AV Results

4.1 SBAV Profit Crosstab

```r
# Define the values for each variable
sprop <- c(0.10, 0.20, 0.30, 0.40, 0.50,
          0.60, 0.70, 0.80, 0.90, 1.00)
array <- c("Fixed", "Tracking")
height <- c(4.6, 6.4, 8.2)
yldvar <- c(0.5, 1, 1.5)
al_regs <- c("Northern", "Central",
             "Black Belt", "Southern")
price <- c(3, 6, 9)
elcprc <- c(0.04) # Electricity Price

# Define the required columns
required_columns <- c("sprop", "array", "height",
                      "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in sbav_profit
missing_columns <- setdiff(required_columns, names(sbav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in sbav_profit: ", paste(missing_columns, collapse = ", "))
}
```

```r
# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3], " ", x[2], " ", x[1]))

# Generate row names using reversed order of expand.grid (without elcprc)
row_names <- apply(expand.grid(price, yldvar, al_regs), 1,
                   function(x) paste0(x[3], " ", x[2], " ", x[1]))

# Create an empty matrix to store the results
result_matrix <- matrix(NA, nrow = length(row_names), ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with all combinations of
# parameters in reversed order (including elcprc for crosstabbing)
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with sbav_profit to get sbav_profit values for each combination
merged_data <- merge(param_combinations,
                     sbav_profit,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data to fill result_matrix with reversed
# column and row names (excluding elcprc in row_name)
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1], " ", x[2], " ", x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price")], 1,
  function(x) paste0(x[1], " ", x[2], " ", x[3]))

# Fill the matrix with sbav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
```

```
  row_data <- merged_data[merged_data$row_name == row_condition, ]

  # Ensure that there are valid matches for col_name before assignment
  col_indices <- match(row_data$col_name,
                       colnames(result_matrix))
  valid_indices <- which(!is.na(col_indices))

  if (length(valid_indices) > 0) {
    result_matrix[i, col_indices[valid_indices]] <- round(row_data$sbav_profit[valid_indices]
  }
}
ct_sbav_pft <- as.data.frame(result_matrix) #Table in Excel.
rm(result_matrix); rm(sprop); rm(array); rm(height);
rm(elcprc); rm(price); rm(yldvar); rm(al_regs)
```

```
write_xlsx(x = ct_sbav_pft %>%
  dplyr::mutate(Row_Names = rownames(ct_sbav_pft)) %>%
  dplyr::select(Row_Names, everything()),
          file = "Results/Profit Ctab SBAV R25.xlsx",
          as_table = TRUE)
dim(ct_sbav_pft)
```

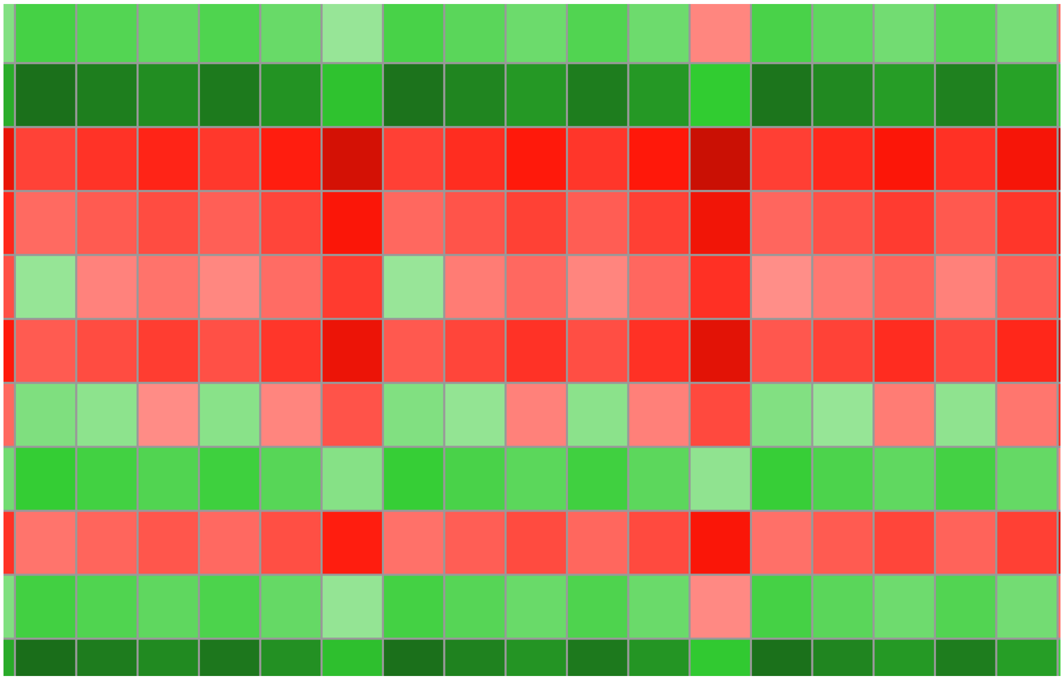
```
[1] 36 60
```

4.2 SBAV Profit Heatmap

```
# Calculate color count based on unique values, excluding zero
colorcount <- length(unique(as.vector(as.matrix(ct_sbav_pft[-1]))))

# Define custom breaks to ensure zero is distinctly marked
# Calculate min and max values to define the range
min_val <- min(ct_sbav_pft, na.rm = TRUE)
max_val <- max(ct_sbav_pft, na.rm = TRUE)

# Create breaks that ensure zero is in the middle
breaks <- seq(min_val, max_val, length.out = colorcount)

# Separate color palettes for negative and positive values
# Negative values: Shades of red
```

```r
neg_colors <- colorRampPalette(c("#890800",
                                 "#FF1709",
                                 "#FF8F89"))(sum(breaks < 0))

# Define the color for zero separately
zero_color <- "#FF8F89"

# Positive values: Shades of green
pos_colors <- colorRampPalette(c("#99E699",
                                 "#32CD32",
                                 "#196719"))(sum(breaks > 0))

# Combine negative colors, zero, and positive colors
custom_colors <- c(neg_colors,
                   zero_color,
                   pos_colors)

# Generate heatmap with the custom color scheme
heatmap_plot <- pheatmap(
  (ct_sbav_pft),
  clustering_distance_rows = "euclidean",
  clustering_distance_cols = "euclidean",
  clustering_method = "complete",
  angle_col = 90,
  na_col = "white",
  color = custom_colors,
  breaks = breaks,
  cutree_rows = 5,
  cutree_cols = 4,
  cluster_rows = FALSE,
  cluster_cols = FALSE,
  show_rownames = TRUE,
  show_colnames = TRUE,
  display_numbers = FALSE,
  number_color = "black",
  fontsize_number = 5,
  number_format = "%.0f",
  cellheight = 24,
  cellwidth = 23,
  fontsize = 18,
  fontsize_row = 22,
  fontsize_col = 22
```

```
)
```



```
ggsave(heatmap_plot,
       height = 18,
       width = 24,
       units = "in",
       limitsize = FALSE,
       file = paste0("Plots/SBAV Profits Ctab R25", ".png"))
```

```
# Calculate color count based on unique values, excluding zero
colorcount <- length(unique(as.vector(as.matrix(ct_sbav_pft[-1]))))

# Define custom breaks to ensure zero is distinctly marked
# Calculate min and max values to define the range
min_val <- min(ct_sbav_pft, na.rm = TRUE)
max_val <- max(ct_sbav_pft, na.rm = TRUE)

# Create breaks that ensure zero is in the middle
breaks <- seq(min_val, max_val, length.out = colorcount)

# Separate color palettes for negative and positive values
# Negative values: Shades of red
```

```r
neg_colors <- colorRampPalette(c("#890800",
                                 "#FF1709",
                                 "#FF8F89"))(sum(breaks < 0))

# Define the color for zero separately
zero_color <- "#FF8F89"

# Positive values: Shades of green
pos_colors <- colorRampPalette(c("#99E699",
                                 "#32CD32",
                                 "#196719"))(sum(breaks > 0))

# Combine negative colors, zero, and positive colors
custom_colors <- c(neg_colors,
                   zero_color,
                   pos_colors)

# Generate heatmap with the custom color scheme
heatmap_plot <- pheatmap(
  (ct_sbav_pft),
  clustering_distance_rows = "euclidean",
  clustering_distance_cols = "euclidean",
  clustering_method = "complete",
  angle_col = 90,
  na_col = "white",
  color = custom_colors,
  breaks = breaks,
  cutree_rows = 5,
  cutree_cols = 4,
  cluster_rows = FALSE,
  cluster_cols = FALSE,
  show_rownames = TRUE,
  show_colnames = TRUE,
  display_numbers = TRUE,
  number_color = "black",
  fontsize_number = 5,
  number_format = "%.0f",
  cellheight = 24,
  cellwidth = 23,
  fontsize = 18,
  fontsize_row = 22,
  fontsize_col = 22
```

```
)
```


```r
ggsave(heatmap_plot,
       height = 18,
       width = 24,
       units = "in",
       limitsize = FALSE,
       file = paste0("Plots/SBAV Profits Ctab R25 Values", ".png"))
```

4.3 SBAV Profit Manuscript

```r
# Define the values for each variable
sprop <- c(0, 0.25, 0.50, 0.75, 1.00)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
yldvar <- c(1) # Yield Variability
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(6) # Crop Price
elcprc <- c(0.04) # Electricity Price
```

```r
# Define the required columns
required_columns <- c("sprop", "array", "height",
                      "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in tav_profit
missing_columns <- setdiff(required_columns,
                           names(sbav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in tav_profit: ",
       paste(missing_columns,
             collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, sprop), 1,
                   function(x) paste0(x[2], x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               yldvar,
                               al_regs,
                               array), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA,
                        nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)
```

```r
# Merge with tav_profit to get tav_profit values for each combination
merged_data <- merge(param_combinations,
                     sbav_profit,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data to fill result_matrix with
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "height")], 1,
  function(x) paste0(x[1], x[2]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price",
                  "elcprc", "array")], 1,
  function(x) paste0(
                     x[4],
                     x[3],
                     x[2],
                     x[1],
                     x[5]))

# Fill the matrix with tav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$sbav_profit, 0)
  }
}
sbav_prof_man <- as.data.frame(result_matrix) # Table in Excel.
sbav_prof_man
```

```
                         04.6 06.4 08.2 0.254.6 0.256.4 0.258.2 0.54.6 0.56.4
0.0461NorthernFixed      4176 4176 4176    3129    2098     171   1730   -675
0.0461CentralFixed       4176 4176 4176    3323    2292     365   2183   -222
0.0461Black BeltFixed    4176 4176 4176    3450    2419     492   2478     73
0.0461SouthernFixed      4176 4176 4176    3495    2465     537   2585    180
```

```
0.0461NorthernTracking   4176 4176 4176    3339    2582    1826   2221    456
0.0461CentralTracking    4176 4176 4176    3629    2873    2116   2898   1134
0.0461Black BeltTracking 4176 4176 4176    3772    3016    2260   3232   1468
0.0461SouthernTracking   4176 4176 4176    3860    3104    2348   3438   1674
                         0.58.2 0.754.6 0.756.4 0.758.2  14.6  16.4   18.2
0.0461NorthernFixed       -5172     333   -3446  -10513 -1064 -6218 -15855
0.0461CentralFixed        -4720    1044   -2735   -9802   -95 -5248 -14885
0.0461Black BeltFixed     -4424    1508   -2271   -9338   538 -4615 -14252
0.0461SouthernFixed       -4317    1677   -2102   -9169   768 -4385 -14022
0.0461NorthernTracking    -1308    1104   -1669   -4442   -14 -3795  -7576
0.0461CentralTracking      -631    2168    -605   -3378  1438 -2343  -6124
0.0461Black BeltTracking   -297    2693     -80   -2853  2154 -1628  -5409
0.0461SouthernTracking      -91    3017     244   -2529  2595 -1186  -4967
```

```
write_xlsx(x = sbav_prof_man %>%
  dplyr::mutate(Row_Names = rownames(sbav_prof_man)) %>%
  dplyr::select(Row_Names, everything()),
           file = "Results/Profit SBAV Manuscript R25.xlsx",
           as_table = TRUE)
# Display the result matrix
rm(result_matrix); rm(sprop); rm(array); rm(height);
rm(elcprc); rm(price); rm(yldvar); rm(al_regs)
```

4.4 SBAVP - Strawberry Profit Crosstab

- Row naming: Electricity Price_Crop Price_Solar Proportion_Alabama Regions
- Column naming: Solar Proportion_Array Types_Solar Panel Height.
- Solar Proportion can be converted to total number of panels.
- Only selected values from each variables are extracted for tabulation purpose.
- Values displayed in the table are profit from Strawberry AV system.

```
# Define the values for each variable
sprop <- c(0, 0.05, 0.10, 0.15, 0.20, 0.25,
           0.30, 0.35, 0.40, 0.45, 0.50,
           0.55, 0.60, 0.65, 0.70, 0.75,
           0.80, 0.85, 0.90, 0.95, 1.00)
array <- c("Fixed", "Tracking")
height <- c(4.6, 6.4, 8.2)
yldvar <- c(0, 0.10, 0.20, 0.30, 0.40, 0.50,
```

```r
            0.60, 0.70, 0.80, 0.90, 1.00,
            1.10, 1.20, 1.30, 1.40, 1.50,
            1.60, 1.70, 1.80, 1.90, 2.00)
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(3, 4, 5, 6, 7, 8, 9)
elcprc <- c(0.03, 0.04, 0.05)

# Define the required columns
required_columns <- c("sprop", "array", "height",
                      "al_regs", "yldvar", "price", "elcprc")

# Check if the columns exist in sbav_profit
missing_columns <- setdiff(required_columns,
                           names(sbav_profit))
if (length(missing_columns) > 0) {
  stop("Missing columns in sbav_profit: ",
       paste(missing_columns, collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3], x[2], x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               yldvar,
                               al_regs), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA, nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  yldvar = yldvar,
                                  al_regs = al_regs,
```

```r
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tav_profit to get sbav_profit values for each combination
merged_data <- merge(param_combinations,
                     sbav_profit,
                     by = required_columns,
                     all.x = TRUE)

# Reshape merged_data to fill result_matrix with
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1],
                     x[2],
                     x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "yldvar", "price", "elcprc")], 1,
  function(x) paste0(x[4],
                     x[3],
                     x[2],
                     x[1]))

# Fill the matrix with sbav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$sbavp_wocp, 2)
  }
}
ct_sbavp_wocp <- as.data.frame(result_matrix) #Table in Excel.
rm(result_matrix)
```

```r
write.csv(as.data.frame(ct_sbavp_wocp),
          row.names = TRUE,
```

```
          #col.names = TRUE,
          file = "Results/ct_sbavp_wocp R25.csv")
dim(ct_sbavp_wocp)
```

```
[1] 1764  126
```

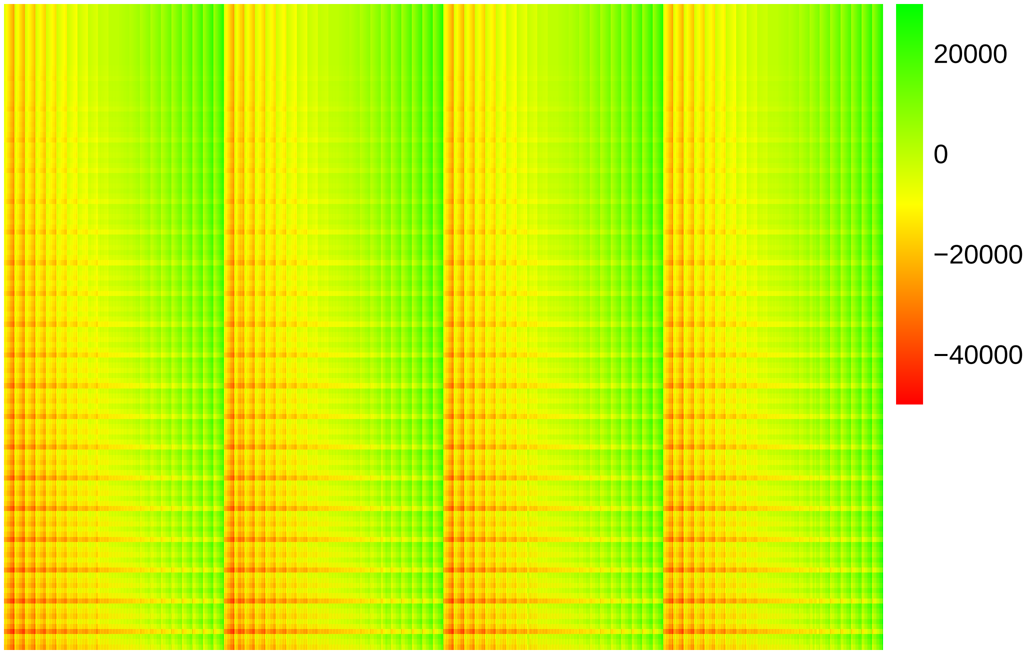
4.5 SBAVP - Strawberry Profit Heatmap

- Heatmap of 324*30 dimension matrix.

```
colorcount = length(unique(as.vector(as.matrix(ct_sbavp_wocp[-1]))))
colorcount
```

```
[1] 149593
```

```
heatmap_plot <- pheatmap(t(ct_sbavp_wocp),
                         #clustering_distance_rows = "correlation",
                         clustering_distance_rows = "euclidean",
                         clustering_distance_cols = "euclidean",
                         clustering_method = "complete",
                         color = colorRampPalette(c("red",
                                                    "yellow",
                                                    "green"))(colorcount),
                         #cutree_rows = 5,
                         #cutree_cols = 4,
                         cluster_rows = FALSE,
                         cluster_cols = FALSE,
                         show_rownames = FALSE,
                         show_colnames = FALSE,
                         display_numbers = FALSE,
                         number_format = "%.2f",
                         #cellheight = 3,
                         #cellwidth = 3
                         )
```




```
ggsave(heatmap_plot,
       height = 8,
       width = 12,
       units = "in",
       file = paste0("Plots/gp_sbavp_wocp R25", ".png"))
rm(heatmap_plot, colorcount)
```

4.6 SBAV Breakeven Yield Crosstab

```
sprop <- c(0.05, 0.25, 0.50, 0.75, 0.80, 0.85, 0.90, 1)
array <- c("Fixed", "Tracking") # Solar Array
height <- c(4.6, 6.4, 8.2) # Panel height
al_regs <- c("Northern", "Central", "Black Belt", "Southern")
price <- c(3, 6, 9)
elcprc <- c(0.02, 0.03, 0.04) # Electricity Price
yldvar <- c(0, 0.10, 0.20, 0.30, 0.40,
            0.50, 0.60, 0.70, 0.80, 0.90, 1.00,
            1.10, 1.20, 1.30, 1.40, 1.50, 1.60,
            1.70, 1.80, 1.90, 2.00)

# Define the required columns
```

```r
required_columns <- c("sprop", "array", "height",
                      "al_regs", "price", "elcprc")

# Check if the columns exist in sbav_profit
missing_columns <- setdiff(required_columns,
                           names(sbav_be_yld))
if (length(missing_columns) > 0) {
  stop("Missing columns in sbav_be_yld: ",
       paste(missing_columns, collapse = ", "))
}

# Generate column names using reversed order of expand.grid
col_names <- apply(expand.grid(height, array, sprop), 1,
                   function(x) paste0(x[3], x[2], x[1]))

# Generate row names using reversed order of expand.grid
row_names <- apply(expand.grid(elcprc,
                               price,
                               al_regs), 1,
                   function(x) paste0(x, collapse = ""))

# Create an empty matrix to store the results
result_matrix <- matrix(NA, nrow = length(row_names),
                        ncol = length(col_names))
colnames(result_matrix) <- col_names
rownames(result_matrix) <- row_names

# Create a data frame with
# all combinations of parameters in reversed order
param_combinations <- expand.grid(elcprc = elcprc,
                                  price = price,
                                  al_regs = al_regs,
                                  height = height,
                                  array = array,
                                  sprop = sprop)

# Merge with tavp_be_yld to get tavp_be_yld
# values for each combination
merged_data <- merge(param_combinations,
                     sbav_be_yld,
                     by = required_columns,
                     all.x = TRUE)
```

```
# Reshape merged_data to fill result_matrix with
# reversed column and row names
merged_data$col_name <- apply(
  merged_data[, c("sprop", "array", "height")], 1,
  function(x) paste0(x[1], x[2], x[3]))

merged_data$row_name <- apply(
  merged_data[, c("al_regs", "price", "elcprc")], 1,
  function(x) paste0(x[3],
                     x[2],
                     x[1]))

# Fill the matrix with sbav_profit values
for (i in seq_len(nrow(result_matrix))) {
  row_condition <- rownames(result_matrix)[i]
  row_data <- merged_data[
    merged_data$row_name == row_condition, ]
  if (nrow(row_data) > 0) {
    result_matrix[i,
                  match(row_data$col_name,
                        colnames(result_matrix))] <- round(
                          row_data$yield, 0)
  }
}
ct_sbav_be_yld <- as.data.frame(result_matrix) # Table in Excel.
```

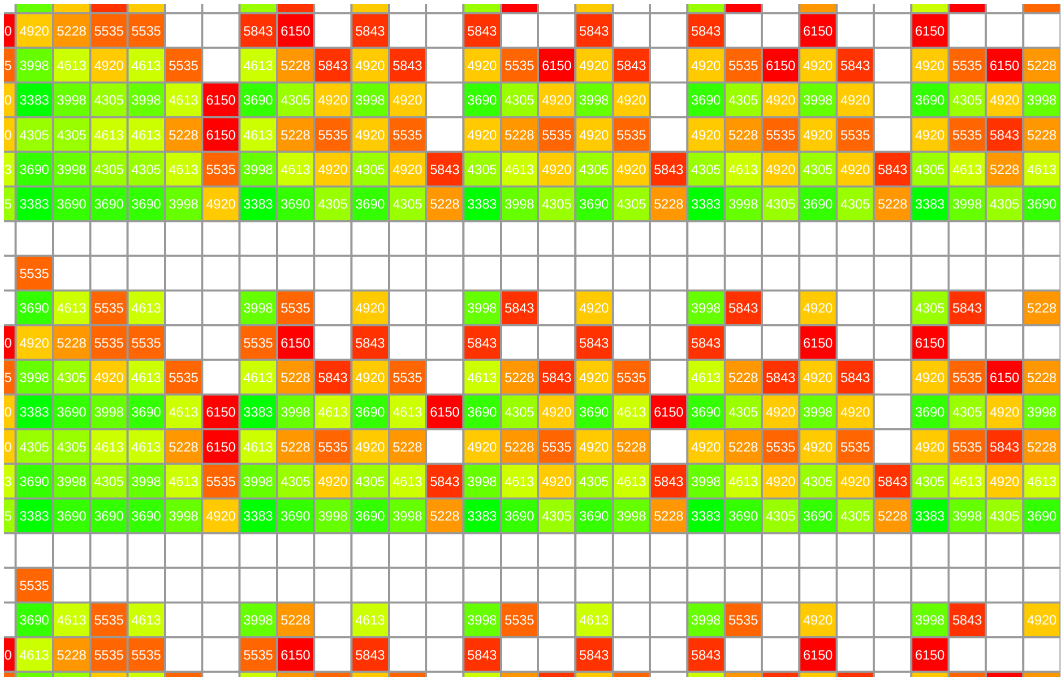
```
write.csv(as.data.frame(ct_sbav_be_yld),
          row.names = TRUE,
          file = "Results/ct_sbav_be_yld R25.csv")
dim(ct_sbav_be_yld)
```

```
[1] 36 48
```

4.7 SBAV Breakeven Yield Heatmap

```
uniquevalue <- unique(as.vector(as.matrix(ct_sbav_be_yld[-1])))
colorcount <- length(unique(as.vector(as.matrix(ct_sbav_be_yld[-1]))))
heatmap_plot <- pheatmap((ct_sbav_be_yld),
                         #clustering_distance_rows = "correlation",
```

```
                          clustering_distance_rows = "euclidean",
                          clustering_distance_cols = "euclidean",
                          clustering_method = "complete",
                          angle_col = 90,
                          na_col = "white",
                          color = colorRampPalette(c("green",
                                                     "yellow",
                                                     "red"))(colorcount),
                          cellheight = 13,
                          cellwidth = 14,
                          fontsize = 12,
                          fontsize_row = 12,
                          fontsize_col = 12,
                          number_color = "white",
                          fontsize_number = 5,
                          cluster_rows = FALSE,
                          cluster_cols = FALSE,
                          show_rownames = TRUE,
                          show_colnames = TRUE,
                          display_numbers = TRUE,
                          number_format = "%.0f",
                          legend_breaks = uniquevalue
                          )
```



```r
ggsave(heatmap_plot,
       height = 8,
       width = 12,
       units = "in",
       file = paste0("Plots/gp_sbav_be_yld R25", ".png"))
rm(heatmap_plot); rm(colorcount); rm(uniquevalue)
```

4.8 Plot Strawberry Profit by Panels

You can see plot breakdown based on yield variation, crop price, and electricity price. You can see variation for all solar proportion in one facet of the chart. Each facet of the chart contain av profit three heights of solar panels, four regions of AL, two array types.

```r
combinations <- expand.grid(
  yldvar = c(0, 0.1, 0.3, 0.5, 0.7, 1, 1.20, 1.5, 1.80, 2), # Yield
  price = c(3, 6, 9), # Strawberry price
  elcprc = c(0.03, 0.04, 0.05) # Electricity price
)

# Iterate over the combinations and create the plots
for (combo in seq_len(nrow(combinations))) {
  filtered_data <- sbav_profit %>%
```

```r
  filter(
    yldvar == combinations$yldvar[combo],
    price == combinations$price[combo],
    elcprc == combinations$elcprc[combo]
  )
# If by panel, put panels below in color and group.
sbav_sp_plot <- ggplot(data = filtered_data,
                      mapping = aes(x = al_regs,
                                    y = sbav_profit,
                                    color = factor(panels),
                                    group = factor(panels))) +
  geom_line() +
  geom_point() +
  facet_grid(height ~ array,
             labeller = as_labeller(
               c(
                 "4.6" = "4.6 ft. Height",
                 "6.4" = "6.4 ft. Height",
                 "8.2" = "8.2 ft. Height",
                 Tracking = "Single Axis Rotation",
                 Fixed = "Fixed Open Rack"
                 ))) +
  guides(color = guide_legend(ncol = 1,
                              reverse = TRUE)) +
  scale_x_discrete(limits = c("Northern", "Central",
                              "Black Belt", "Southern"),
                   labels = c("North", "Center",
                              "B Belt", "South")) +
  guides(color = guide_legend(ncol = 2,
                              reverse = TRUE)) +
  labs(x = "Regions of Alabama",
       y = "Profit ($) from Strawberry Agrivoltaic System",
       color = "Number of Solar \n Panels per Acre",
       title = (list(combinations[combo,]))
       ) +
  theme(strip.background = element_blank())
# Add horizontal line at y = 0 if y has both positive and negative values
if (min(filtered_data$sbav_profit) < 0 &
    max(filtered_data$sbav_profit) > 0) {
  sbav_sp_plot <- sbav_sp_plot +
    geom_hline(yintercept = 0,
               linewidth = 0.30,
```

```
                  linetype = "dashed",
                  color = "black")
  }
  print(combinations[combo,])
  print(sbav_sp_plot)
  ggsave(file = paste0("Plots/sbav_sp_ R25", combo, ".png"))
  #break
}
```

4.9 Plot Strawberry Profit by Yields

You can see plot breakdown based on solar proportion, crop price, and electricity price. You can see variation for all crop yield variation in one facet of the chart. Each facet of the chart contain av profit three heights of solar panels, four regions of AL, two array types.

```
combinations <- expand.grid(
  sprop = c(0, 0.25, 0.50, 0.75, 1.00), # Solar proportion
  price = c(3, 6, 9), # Strawberry price
  elcprc = c(0.03, 0.04, 0.05) #Electricity price
)

# Iterate over the combinations and create the plots
for (combo in seq_len(nrow(combinations))) {
  filtered_data <- sbav_profit %>%
    filter(
      sprop == combinations$sprop[combo],
      price == combinations$price[combo],
      elcprc == combinations$elcprc[combo]
    )
  # If by yield, put yield below in color and group.
  sbav_yv_plot <- ggplot(data = filtered_data,
                         mapping = aes(x = al_regs,
                                       y = sbav_profit,
                                       color = factor(yield),
                                       group = factor(yield))) +
    geom_line() +
    geom_point() +
    facet_grid(height ~ array,
               labeller = as_labeller(
                 c(
                   "4.6" = "4.6 ft. Height",
```

```
                   "6.4" = "6.4 ft. Height",
                   "8.2" = "8.2 ft. Height",
                   Tracking = "Single Axis Rotation",
                   Fixed = "Fixed Open Rack"
                   ))) +
    guides(color = guide_legend(ncol = 1,
                                reverse = TRUE)) +
    scale_x_discrete(limits = c("Northern", "Central",
                                "Black Belt", "Southern"),
                     labels = c("North", "Center",
                                "B Belt", "South")) +
    guides(color = guide_legend(ncol = 2,
                                reverse = TRUE)) +
    labs(x = "Regions of Alabama",
         y = "Profit ($) from Strawberry Agrivoltaic System",
         color = "Strawberry Yield \n (25 Lb Buckets)",
         title = (list(combinations[combo,]))
         ) +
    theme(strip.background = element_blank())
  # Add horizontal line at y = 0 if y has both positive and negative values
  if (min(filtered_data$sbav_profit) < 0 &
      max(filtered_data$sbav_profit) > 0) {
    sbav_yv_plot <- sbav_yv_plot +
      geom_hline(yintercept = 0,
                 linewidth = 0.30,
                 linetype = "dashed",
                 color = "black")
  }
  print(combinations[combo,])
  print(sbav_yv_plot)
  ggsave(file = paste0("Plots/sbav_yv_ R25", combo, ".png"))
  #break
}
```