# Application of Python on the agriculture allocation

How to arrange our plants?

?

# Catalogue

# Background

## Village

**Greenhouse**

more harvest

normal selling price

**transformation**

**Organic planting**

lower harvest rate

higher profit

**3 main crops**

higher profit
more fertilizer
more labor
higher transportation cost

lower resource requirement

larger growth space

# Modeling: Linear Programming Model Assumptions

## 4 Assumptions

1. Proportionality
2. Additivity
3. Divisibility
4. Certainty

# Modeling: Linear Programming Model

## 1 Production and Transportation Demands (per 10 plants)

$a_{i,j}$ ($i$=1, 2, …, 5, $j$=1, 2, …, 6): demand for resources of each crop under two planting patterns

| | Greenhouse | | | Organic | | |
|---|---|---|---|---|---|---|
| | Strawberry | Potato | Pumpkin | Strawberry | Potato | Pumpkin |
| **Land** | $a_{1,1}$ | $a_{1,2}$ | $a_{1,3}$ | $a_{1,4}$ | $a_{1,5}$ | $a_{1,6}$ |
| **Workers** | $a_{2,1}$ | $a_{2,2}$ | $a_{2,3}$ | $a_{2,4}$ | $a_{2,5}$ | $a_{2,6}$ |
| **Fertilizer** | $a_{3,1}$ | $a_{3,2}$ | $a_{3,3}$ | $a_{3,4}$ | $a_{3,5}$ | $a_{3,6}$ |
| **Transportation** | $a_{4,1}$ | $a_{4,2}$ | $a_{4,3}$ | $a_{4,4}$ | $a_{4,5}$ | $a_{4,6}$ |
| **Pesticide** | $a_{5,1}$ | $a_{5,2}$ | $a_{5,3}$ | $a_{5,4}$ | $a_{5,5}$ | $a_{5,6}$ |

# Modeling: Linear Programming Model

**2** **Limitation of Production and Transportation Resources (per 10 plants)**

$b_n$ ($n$=1, 2, …, 5): limitation of each resource

| Resources | Limitation |
|---|---|
| Land | $b_1$ |
| Workers | $b_2$ |
| Fertilizer | $b_3$ |
| Transportation | $b_4$ |
| Pesticide | $b_5$ |

$b_6$ land area for organic ≥ $b_1/3$

# Modeling: Linear Programming Model

**3** **Total annual profit of each planting pattern (per 10 plants)**

$C_j$ ($j$=1, 2, …, 6): respective profit → $Z$: aggregated profit

| | Strawberry | Potato | Pumpkin |
|---|---|---|---|
| Greenhouse | $C_1$ | $C_2$ | $C_3$ |
| Organic | $C_4$ | $C_5$ | $C_6$ |

**4** **Decision variables**

$x_j$ ($j$ = 1, 2, …, 6 and $x_j \geq 0$) : the number of plants (counted by tens) under different planting patterns

| | Strawberry | Potato | Pumpkin |
|---|---|---|---|
| Greenhouse | $x_1$ | $x_2$ | $x_3$ |
| Organic | $x_4$ | $x_5$ | $x_6$ |

# Numerical example: background data

## 1 Resources Demands

$a_{i,j}$ ($i$=1, 2, …, 5, $j$=1, 2, …, 6): demand for resources of each crop under two planting patterns

| | Greenhouse | | | Organic | | |
|---|---|---|---|---|---|---|
| | Strawberry | Potato | Pumpkin | Strawberry | Potato | Pumpkin |
| Land ($m^2$) | 1 | 1.5 | 3 | 1 | 1.5 | 3 |
| Workers (person) | 0.4 | 0.3 | 0.2 | 0.6 | 0.5 | 0.4 |
| Fertilizer (kg) | 2.5 | 1.4 | 1.8 | 3 | 1.7 | 2.2 |
| Transportation (van) | 0.32 | 0.2 | 0.17 | 0.38 | 0.22 | 0.2 |
| Pesticide (kg) | 2.5 | 0.4 | 0.5 | 0 | 0 | 0 |

MORE OTHER RESOURCES!

NO PESTICIDE!

# Numerical example: background data

## 2 Constraints

$b_n$ ($n$=1, 2, …, 5): limitation of each resource

| Resources | Limitation |
|---|---|
| Land ($m^2$) | 450 |
| Workers (person) | 90 |
| Fertilizer (kg) | 500 |
| Transportation (van) | 60 |
| Pesticide (kg) | 150 |

$b_6$ land area for organic ≥150

## 3 Annual Profit

$C_j$ ($j$=1, 2, …, 6): respective profit

| | Strawberry | Potato | Pumpkin |
|---|---|---|---|
| Greenhouse | 72 | 43 | 46 |
| Organic | 79 | 48 | 52 |

# Numerical example: modeling

## 1 Dependent Variable

Total annual profit

$$Z = 72x_1 + 43x_2 + 46x_3 + 79x_4 + 48x_5 + 52x_6$$ → Maximize Z

## 2 Constraints

**1. Production & transportation budgets**

$$x_1 + 1.5x_2 + 3x_3 + x_4 + 1.5x_5 + 3x_6 \leq 450$$

$$0.4x_1 + 0.3x_2 + 0.2x_3 + 0.6x_4 + 0.5x_5 + 0.4x_6 \leq 90$$

$$2.5x_1 + 1.4x_2 + 1.8x_3 + 3x_4 + 1.7x_5 + 2.2x_6 \leq 500$$

$$0.32x_1 + 0.2x_2 + 0.17x_3 + 0.38x_4 + 0.22x_5 + 0.2x_6 \leq 60$$

$$2.5x_1 + 0.4x_2 + 0.5x_3 \leq 150$$

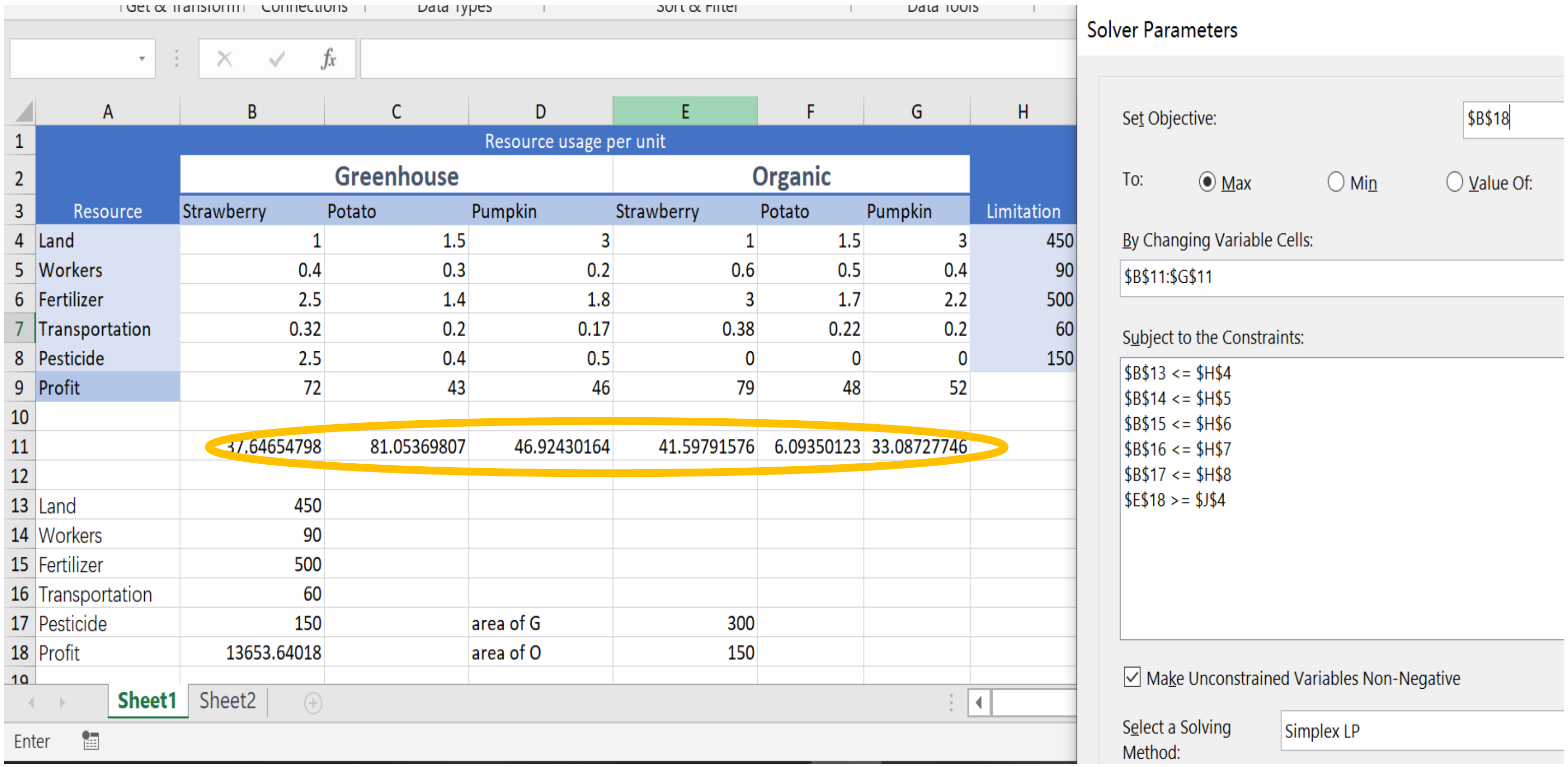
**2. Government requirement**

$$x_4 + 1.5x_5 + 3x_6 \geq 150$$

**3. Nonnegativity**

$$x_j \geq 0, \quad for\ i = 1,2,\ldots,6$$

# Numerical example: Excel Solver



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | | Resource usage per unit | | | | | | |
| 2 | | Greenhouse | | | Organic | | | |
| 3 | Resource | Strawberry | Potato | Pumpkin | Strawberry | Potato | Pumpkin | Limitation |
| 4 | Land | 1 | 1.5 | 3 | 1 | 1.5 | 3 | 450 |
| 5 | Workers | 0.4 | 0.3 | 0.2 | 0.6 | 0.5 | 0.4 | 90 |
| 6 | Fertilizer | 2.5 | 1.4 | 1.8 | 3 | 1.7 | 2.2 | 500 |
| 7 | Transportation | 0.32 | 0.2 | 0.17 | 0.38 | 0.22 | 0.2 | 60 |
| 8 | Pesticide | 2.5 | 0.4 | 0.5 | 0 | 0 | 0 | 150 |
| 9 | Profit | 72 | 43 | 46 | 79 | 48 | 52 | |
| 10 | | | | | | | | |
| 11 | | 37.64654798 | 81.05369807 | 46.92430164 | 41.59791576 | 6.09350123 | 33.08727746 | |
| 12 | | | | | | | | |
| 13 | Land | 450 | | | | | | |
| 14 | Workers | 90 | | | | | | |
| 15 | Fertilizer | 500 | | | | | | |
| 16 | Transportation | 60 | | | | | | |
| 17 | Pesticide | 150 | | area of G | 300 | | | |
| 18 | Profit | 13653.64018 | | area of O | 150 | | | |



$$(x_1, x_2, x_3, x_4, x_5, x_6) = (37.65, 81.05, 46.92, 41.60, 6.09, 33.09)$$

$$Z = 13653.64$$

# Numerical example: Sensitivity analysis

## 1 Sensitivity analysis on constraints

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $B$13 | Land | 450 | 2.103053988 | 450 | 112.5668449 | 131.147541 |
| $B$14 | Workers | 90 | 8.034447822 | 90 | 6.882432636 | 0.578853293 |
| $B$15 | Fertilizer | 500 | 9.666377189 | 500 | 21.05263158 | 5.904628331 |
| $B$16 | Transportation | 60 | 114.9153278 | 60 | 0.263289556 | 2 |
| $B$17 | Pesticide | 150 | 2.297727602 | 150 | 105.8563536 | 22.75675676 |
| $E$18 | area of Organic | 150 | 0.590678825 | 150 | 10.81706064 | 51.67269439 |

Land
Pesticide

Positive shadow price

High allowable increase

Workers
Fertilizer

Higher shadow price

Less allowable increase

Transportation

High shadow price

No allowable increase in actual

# Numerical example: Sensitivity analysis

## 1 Sensitivity analysis on profit $C_i$

Variable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $B$11 | Strawberry (G) | 37.64654798 | 0 | 72 | 18.91927083 | 5.187908497 |
| $C$11 | Potato (G) | 81.05369807 | 0 | 43 | 0.925396825 | 2.835535714 |
| $D$11 | Pumpkin (G) | 46.92430164 | 0 | 46 | 5.925 | 0.891437309 |
| $E$11 | Strawberry (O) | 41.59791576 | 0 | 79 | 5.847145488 | 7.773333333 |
| $F$11 | Potato (O) | 6.09350123 | 0 | 48 | 4.965290807 | 0.763233879 |
| $G$11 | Pumpkin (O) | 33.08727746 | 0 | 52 | 0.922468354 | 9.753685504 |

Potato (G)
Pumpkin (O)

↓

Sensitive when profit increases

Pumpkin (G)
Potato (O)

↓

Sensitive when profit decreases

Strawberry (G)
Strawberry (O)

↓

Insensitive

# Conclusion

**Model**: linear programming model (4 assumptions)

**Method**: Excel Solver (maximize total profit with 6 constraints)

**Sensitivity analysis**: check whether the optimal solution is sensitive to changes in model parameters

Make appropriate decisions and adjustments based on LP analysis

# Thanks for watching!