“OPTIMIZATION TECHNIQUES FOR REAL-WORLD PROBLEMS”

“Healthcare, Agriculture, Water Resource Management, and Carbon Sequestration”

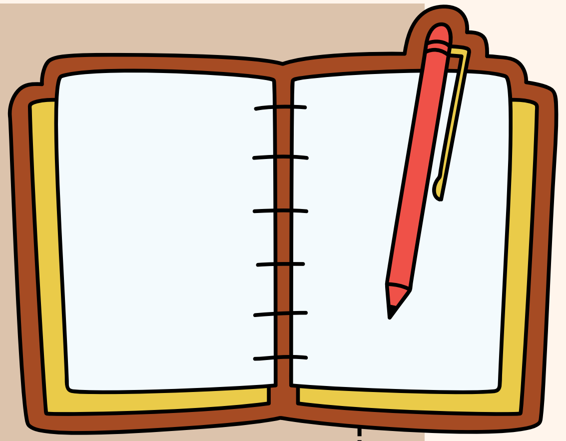
Presented by SAHIL

HEALTHCARE: OPTIMIZING VACCINE DISTRIBUTION

Example : Ensuring equitable and efficient distribution of vaccines across regions, especially during health crises like a pandemic, is a critical challenge. This requires balancing limited vaccine supply with population needs, prioritizing high-risk areas, and minimizing transportation costs.

Objective : To maximize population coverage while minimizing costs and adhering to vaccine
supply constraints.

HEALTHCARE: OPTIMIZING VACCINE DISTRIBUTION



Decision Variables:

x_1 = Vaccines allocated to Region A

x_2 = Vaccines allocated to Region B

x_3 = Vaccines allocated to Region C

Objective Function:

Minimize total cost: $Z=c_1x_1+c_2x_2+c_3x_3$

Constraints:

Total Supply Constraint:

$x_1+x_2+x_3 \leq S$(Total vaccine supply)

Demand Constraints for Each Region:

- $x_1 \leq P_1$(Region A demand)
- $x_2 \leq P_2$(Region B demand)
- $x_3 \leq P_3$(Region C demand)

Non-Negativity Constraints:$x_1,x_2,x_3 \geq 0 x_1,x_2,x_3 \geq 0$

HEALTHCARE: OPTIMIZING VACCINE DISTRIBUTION

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	SOLUTION Region A	400	0	5	1E+30	1
$C$2	SOLUTION Region B	350	0	7	1E+30	3
$D$2	SOLUTION Region C	250	0	4	1	4

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$E$5	Constraint 1 (Vaccine Supply: Total ≤ 1000) LHS	1000	4	1000	50	250
$E$6	Constraint 2 (Population Demand for A) LHS	400	1	400	250	50
$E$7	Constraint 3 (Population Demand for B) LHS	350	3	350	250	50
$E$8	Constraint 4 (Population Demand for C) LHS	250	0	300	1E+30	50

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$E$2	SOLUTION Z	0	5450

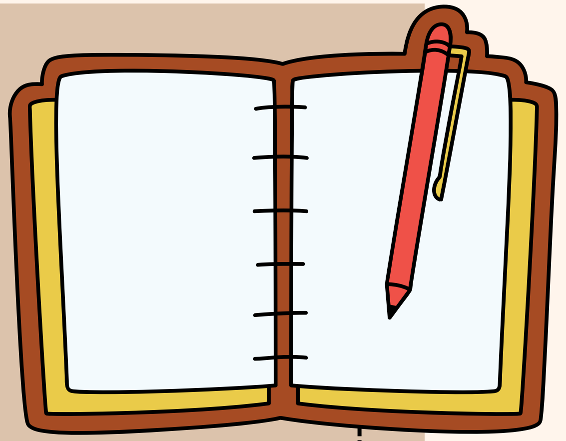
Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	SOLUTION Region A	0	400	Contin
$C$2	SOLUTION Region B	0	350	Contin
$D$2	SOLUTION Region C	0	250	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$E$5	Constraint 1 (Vaccine Supply: Total ≤ 1000) LHS	1000	$E$5<=$G$5	Binding	0
$E$6	Constraint 2 (Population Demand for A) LHS	400	$E$6<=$G$6	Binding	0
$E$7	Constraint 3 (Population Demand for B) LHS	350	$E$7<=$G$7	Binding	0
$E$8	Constraint 4 (Population Demand for C) LHS	250	$E$8<=$G$8	Not Binding	50

HEALTHCARE: OPTIMIZING VACCINE DISTRIBUTION



- The solver found an optimal solution where:
  - Region A receives 400 vaccines
  - Region B receives 350 vaccines
  - Region C receives 250 vaccines
- The total cost (Z) is 5450.
- The supply constraint (1000 vaccines) is fully used, meaning we cannot distribute more without increasing supply.

✅ Key takeaway: The vaccines were distributed efficiently, and supply was the biggest limiting factor.

Sensitivity Report Explanation

- Shadow price for total supply = 4
- → If we get one more vaccine, cost increases by 4 units.
- Region C’s constraint is not binding (50 extra vaccines could go there without affecting the solution).
- Allowable increase/decrease shows how much we can change the transportation cost per region before it impacts the allocation.

✅ Key takeaway: Supply constraints limit distribution, and increasing vaccines slightly would help some regions without increasing costs too much.

Limits Report Explanation

- If we increase supply beyond 1000 vaccines, cost efficiency will change.
- If the transportation cost of Region B increases, it could shift vaccine allocation to Region A or C.

✅ Key takeaway: We should monitor changes in transportation costs because they affect optimal distribution.

AGRICULTURE: OPTIMIZING ORGANIC FARMING

Example : Farmers practicing organic farming must optimize land use, fertilizer distribution,
and crop selection to maximizing yields.

Objective : To maximize yields of organic crops while minimizing costs and adhering to
environmental constraints.

AGRICULTURE: OPTIMIZING ORGANIC FARMING

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	SOLUTION (Crop A)	0	-1	3	1	1E+30
$C$2	SOLUTION (Crop B)	500	0	4	1E+30	1
$D$2	SOLUTION (Crop C)	0	-1.5	2.5	1.5	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$E$5	Constraint 1 Land Constraint LHS	500	4	500	1E+30	500
$E$6	Constraint 2 Fertilizer Constraint LHS	0	0	2000	1E+30	2000

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$E$2	SOLUTION Z	0	2000

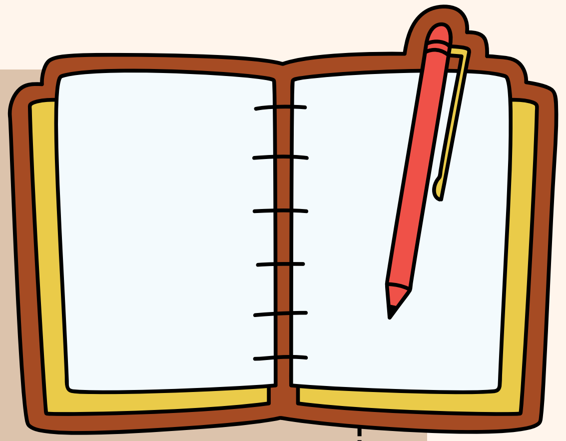
Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	SOLUTION (Crop A)	0	0	Contin
$C$2	SOLUTION (Crop B)	0	500	Contin
$D$2	SOLUTION (Crop C)	0	0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$E$5	Constraint 1 Land Constraint LHS	500	$E$5<=$G$5	Binding	0
$E$6	Constraint 2 Fertilizer Constraint LHS	0	$E$6<=$G$6	Not Binding	2000

AGRICULTURE: OPTIMIZING ORGANIC FARMING



Decision Variables:

x_1 = Acres allocated to Crop A

x_2 = Acres allocated to Crop B

x_3 = Acres allocated to Crop C

Objective Function:

Maximize total yield: $Z=y_1x_1+y_2x_2+y_3x_3$

Constraints:

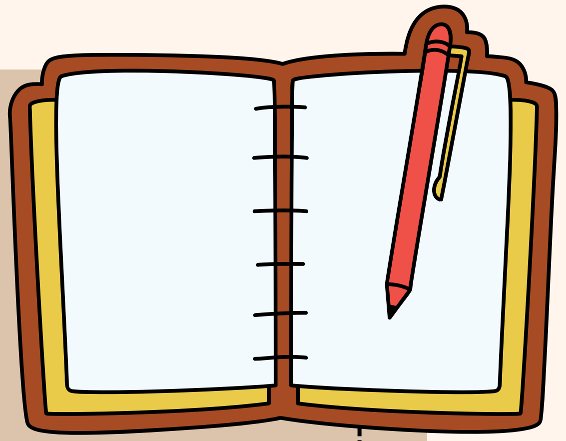
Land Availability Constraint: $x_1+x_2+x_3 \leq L$(Total available land)

Fertilizer Supply Constraint: $f_1x_1+f_2x_2+f_3x_3 \leq F$

where f_1,f_2,f_3f_1,f_2,f_3 are fertilizer requirements per acre, and FF is the total fertilizer available.

Non-Negativity and Integer Constraints: $x_1,x_2,x_3 \geq 0, x_1,x_2,x_3 \in Z^+$(Integer acres)

AGRICULTURE: OPTIMIZING ORGANIC FARMING



Answer Report Explanation

- The solver found an optimal solution where:
  - 500 acres are allocated to Crop B.
  - Crops A and C receive 0 acres.
- Total yield = 2000 units
- Land constraint (500 acres) is fully used, but fertilizer is not a constraint.

✅ Key takeaway: Crop B is the most productive. Crops A and C were not selected due to lower yield per acre.

Sensitivity Report Explanation

- Shadow price for land = 4
- → If we get one more acre of land, yield increases by 4 units.
- Crop A has a reduced cost of -1
- → Crop A would need at least 1 more unit of yield per acre to be included.

✅ Key takeaway: Land is the most valuable resource. Expanding land would improve yields, but fertilizer constraints don't matter right now.

Limits Report Explanation

- If land increases beyond 500 acres, we might see Crop A or C included in the allocation.
- Crop B remains the best choice until its cost or yield changes.

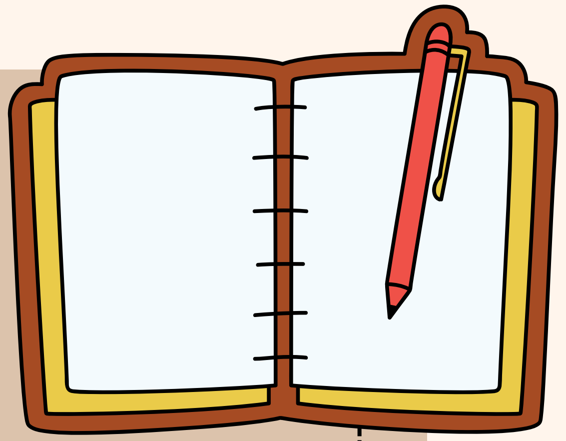
✅ Key takeaway: Investing in land expansion benefits the farm the most.

WATER RESOURCE MANAGEMENT: HOUSEHOLD WATER USAGE

Example : Households must manage water usage efficiently for activities like drinking,
cooking, laundry, and cleaning while staying within local supply limits and maintaining basic
hygiene standards.

Objective : To minimize water consumption while fulfilling household requirements.

WATER RESOURCE MANAGEMENT: HOUSEHOLD WATER USAGE



Decision Variables:

x1 = Water used for drinking (liters/day)

x2 = Water used for cooking (liters/day)

x3 = Water used for laundry (liters/day)

Objective Function:

Minimize total water usage: $Z=x1+x2+x3$

Constraints:

Total Water Allowance:

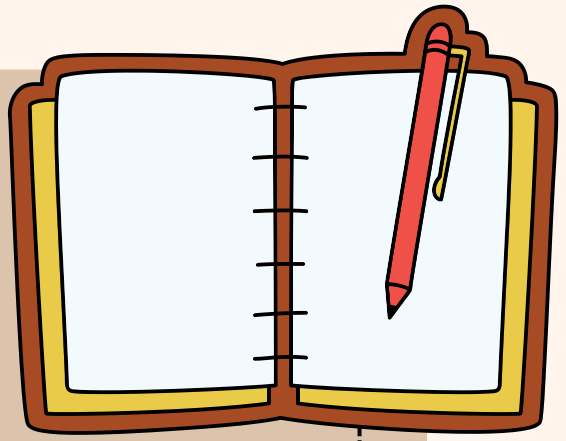
$x1+x2+x3 \le W$(Household’s daily water limit)

Minimum Water Requirements: $x1 \ge d, x2 \ge c, x3 \ge l x1 \ge d, x2 \ge c, x3 \ge l$

where d,c,ld,c,l are the minimum water needs for drinking, cooking, and laundry.

Non-Negativity Constraints: $x1,x2,x3 \ge 0 x1,x2,x3 \ge 0$

WATER RESOURCE MANAGEMENT: HOUSEHOLD WATER USAGE



Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	SOLUTION DRINKING	10	0	1	1E+30	1
$C$2	SOLUTION COOKING	15	0	1	1E+30	1
$D$2	SOLUTION LAUNDRY	0	0	1	1E+30	1

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$E$5	Constraint 1 Water Allowance LHS	25	0	50	1E+30	25
$E$6	Constraint 2 Drinking Minimum LHS	10	1	10	25	10
$E$7	Constraint 3 Cooking Minimum LHS	15	1	15	25	15
$E$8	Constraint 4 Laundry Minimum LHS	0	1	0	25	0

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$E$2	SOLUTION Z	0	25

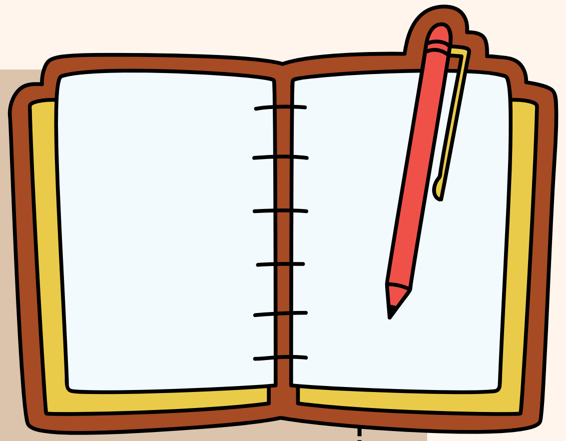
Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	SOLUTION DRINKING	0	10	Contin
$C$2	SOLUTION COOKING	0	15	Contin
$D$2	SOLUTION LAUNDRY	0	0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$E$5	Constraint 1 Water Allowance LHS	25	$E$5<=$G$5	Not Binding	25
$E$6	Constraint 2 Drinking Minimum LHS	10	$E$6>=$G$6	Binding	0
$E$7	Constraint 3 Cooking Minimum LHS	15	$E$7>=$G$7	Binding	0
$E$8	Constraint 4 Laundry Minimum LHS	0	$E$8>=$G$9	Binding	0

WATER RESOURCE MANAGEMENT: HOUSEHOLD WATER USAGE



Answer Report Explanation

- The solver found an optimal solution where:
  - Drinking = 10 liters
  - Cooking = 15 liters
  - Laundry = 0 liters
- Total water used (Z) = 25 liters, meaning we minimized usage while meeting basic needs.

✅ Key takeaway: Drinking and cooking are prioritized over laundry due to constraints.

Sensitivity Report Explanation

- Shadow price for drinking water = 1
- → If we increase drinking water by 1 liter, total water usage increases by 1 liter.
- Laundry has a shadow price of 1
- → If more water is available, laundry would be the first activity to get extra allocation.

✅ Key takeaway: If extra water is available, laundry is the first place it will go.

Limits Report Explanation

- If water allowance increases, it will be allocated to laundry first, then cooking, then drinking.
- If we reduce the allowance below 25 liters, drinking or cooking will be negatively affected.

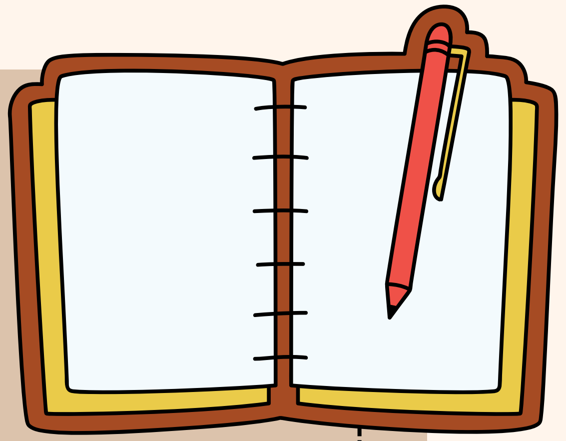
✅ Key takeaway: If we conserve more water, it should go to laundry first.

ENVIRONMENTAL IMPACT: CARBON SEQUESTRATION

Example : Carbon sequestration involves capturing and storing atmospheric carbon dioxide
(CO_2) to mitigate climate change. Optimizing land allocation and sequestration techniques is
crucial for maximizing impact.

Objective : To minimize carbon footprint by maximizing sequestration capacity.

ENVIRONMENTAL IMPACT: CARBON SEQUESTRATION



Decision Variables:

$x1x1$ = Acres allocated to afforestation projects

$x2x2$ = Acres allocated to soil carbon sequestration

$x3x3$ = Acres allocated to mangrove restoration

Objective Function:

Maximize carbon sequestration: $Z=s1x1+s2x2+s3x3$

Constraints:

Total Land Availability:

$x1+x2+x3 \leq L$(Total available land)

Budget Constraint: $c1x1+c2x2+c3x3 \leq Bc1x1+c2x2+c3x3 \leq B$

where $c1,c2,c3c1,c2,c3$ are costs per acre, and BB is the total budget available.

Non-Negativity and Integer Constraints: $x1,x2,x3 \geq 0, x1,x2,x3 \in Z$.

ENVIRONMENTAL IMPACT: CARBON SEQUESTRATION

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	SOLUTION AFFORESTATION	0	0	10	2	0.4
$C$2	SOLUTION SOIL CARBON	0	-1	8	1	1E+30
$D$2	SOLUTION MANGROVES	1000	0	12	0.5	2

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$E$5	Constraint 1 LAND LHS	1000	2	1000	250	0
$E$6	Constraint 2 BUDGET LHS	500000	0.02	500000	0	100000

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$E$2	SOLUTION Z	0	12000

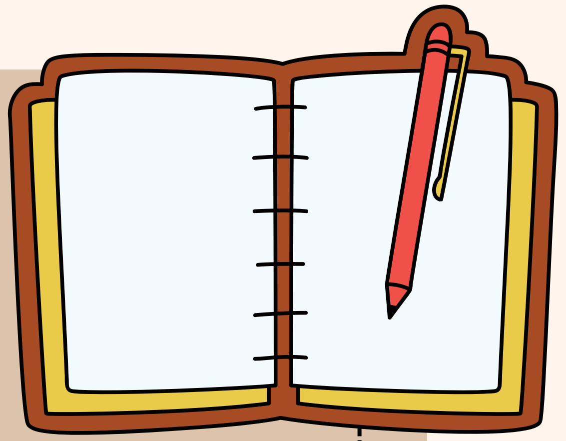
Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	SOLUTION AFFORESTATION	0	0	Contin
$C$2	SOLUTION SOIL CARBON	0	0	Contin
$D$2	SOLUTION MANGROVES	0	1000	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$E$5	Constraint 1 LAND LHS	1000	$E$5<=$G$5	Binding	0
$E$6	Constraint 2 BUDGET LHS	500000	$E$6<=$G$6	Binding	0

ENVIRONMENTAL IMPACT: CARBON SEQUESTRATION



Answer Report Explanation

- The solver found an optimal solution where:
  - 1000 acres are allocated to mangrove restoration.
  - Afforestation and soil sequestration were not included.
- Total carbon sequestration = 12,000 tons CO_2.

✅ Key takeaway: Mangroves provide the best sequestration efficiency.

Sensitivity Report Explanation

- Shadow price for land = 2
- → If we increase land by 1 acre, sequestration increases by 2 tons CO_2.
- Afforestation and soil sequestration have reduced costs
- → They are not part of the solution unless sequestration efficiency increases.

✅ Key takeaway: Mangroves are the best choice. Land expansion would improve carbon capture.

Limits Report Explanation

- If land or budget increases, we can expect more sequestration through mangroves first.
- If afforestation sequestration rate improves, it might become viable.

✅ Key takeaway: Mangroves should be the focus, but afforestation could become competitive with better technology.