Lab 8
Due Nov 17th

This lab will introduce optimization problems with an example of water and resource limited agriculture in a monsoon affected region.

Optimization using Excel's Solver function:

Solver can be found in the Tools menu (on my computer its under Auditing). If it isn't there you can try to add it by choosing "Add-ins". Ask for help if you need it. First we need to prepare some regions in an Excel worksheet for input and output information. Make sure to label things so you can remember what you have done.

1. Set up a list of decision variables, say land for each crop, or amount of ground water, etc. Initialize the decision variables by setting them all to zero.
2. Type into Excel the known information, such as rainfall amount, price of crop, costs of crop, etc.
3. Type in the constraints for your problem, i.e. if total land area may not exceed the given amount type the upper limit.
4. Enter in one cell the objective function that you would like to optimize.
5. Under tools, choose Solver and specify the following:

   Target cell = the objective function you want to optimize

   "Equal to" should be set to "Max"

   "by changing cells" = range of your decision variables

   Add constraints by clicking the add button and set up each comparison, i.e. variable 1 <= some number.
6. A simple example that we discussed in class is attached to illustrate how Solver works.

Project 1: Crop Decision Model Problem:

In Southeastern India, the winter monsoon is very important for local agriculture and the monsoon forecast is extremely important for agricultural planning for farmers. In the problem below, you are asked to help farmers find an optimal way for planting by choosing how much area of each of four types of crops as listed below should be planted. Each crop has a different demand for water which controls the yield. The total land area is fixed (constrained) at 43934 hectares. For this exercise, you'll take the role of advisor to the agricultural planner with the task of optimizing crop profits.

If we define the fraction of the evapotransiration the actual rainfall can provide as FET, then the yield for a given FET per unit hectare of land is as follows:

$$\text{Actual Yield} = (0.8*FET + 1.3*FET^2 - 1.1*FET^3)*\text{ maximum yield}$$

Where

FET = effective rainfall(ER) / Full ET (for each crop)

ER = 0.8 * Rainfall -10

If the fraction of evapotranspiration (FET) is equal to 1, meaning that there are enough rainfall, and actual yield equals maximum yield.

You will see for yourself how actual yield depends on the amount of rainfall or FET in the problem below. Given the actual yield, the profit for each crop is then calculated as

Profit = Land area (in hectare) * (Price of the crop (per/kg) * actual yield – costs)

The full evapotranspiration required for each crop and the costs and selling price for each crop are provided below. You will use the optimization function in Excel (Solver) to find the best scenario for crop planning given the three categories of rainfall (above, normal, below).

Crop Characteristics

Crop	Full ET (mm)	Cost per hectare (Rs)	Price per kg (Rs)	Maximum Yield (kg)
Cotton	700	9838	35.5	800
Groundnuts	556	11338	13.81	1800
Pulses	400	5643	19.25	650
Ragi	405	4166	4.39	1600

Rainfall Categories

Category	Rainfall (mm)
Below Normal	300
Normal	454
Above Normal	600

Optimize the crop profits as follows:

1. First plot the ratio of actual yield and maximum yield as a function of the fraction of evapotranpiration FET (between the range of 0-1.5). What does this curve tell you?
2. Denote the land for each of the four crops as Lc, Lg, Lp, and Lr, for cotton, groundnuts, pulses, and ragi, respectively, construct the optimization problem to maximize the total profit with the constraints that the total land area for all crops can not exceed 43934 hectares, and the land area for each individual crop can not exceed 43934 hectares (see help sheet on using the solver function on excel). What crop plans do you recommend for a farmer practicing rainfed agriculture for each of the monsoon categorical outcomes?
3. You realize that devoting the entire area to a single crop is risky. Why is this so? Adjust the optimization model so no more than 60% of the land can be devoted to a single crop. (This will change your constraints for each individual crop.)
4. Which of the three crop plans you created in #3 would you recommend given the following probabilistic forecast:

   a. Above normal: 60%, Normal: 20%, Below normal: 20%
   b. Above normal: 20%, Normal: 40%, Below normal: 40%

   Use the expected monetary value (EMV) theory and calculate the plan that maximizes the expected value by taking profit for each of individual plans calculated above and multiplying by the probability of occurrence.

Project 2: Water and crop decision problem

After visiting the area you realize many farmers augment rainfall with groundwater pumps which can have electricity costs associated with them called tariffs. You'll need to include this source of water, and possibly additional cost, when considering crop plans.

5. Now the farmers have access to groundwater. How do the crop plans from question 2 change?
6. How much water is used for the three categorical monsoon outcomes?
7. How much water is used when the tariff is 45 Rs/ha-mm and a normal monsoon outcome?
8. If groundwater use exceeds the recharge of groundwater by rainfall, the water table levels can fall, causing the drying of shallow wells and in some areas salt water intrusion. What are some methods that you might advise the agricultural planner to alleviate the overuse of groundwater?