

## Hands-on Tutorial on Optimization

### Exercise Sheet: Farm Planning<sup>1</sup>

The three main inputs to agricultural production are land, labor and water. Their requirements vary throughout the year and for different crop activities. In this exercise, we treat the planning of a small family farm in a developing country. All requirements are specified on a monthly basis, and we assume that we know them with certainty. All tables and necessary data are given in data files.

The farm has 10 hectares of land which the family can use for different crops. Due to crop rotation, different crops use the land differently during each month. This is depicted in Table 1.

	wheat	beans	onions	cotton	maize	tomatoes
Jan	1	1	1			
Feb	1	1	1			
Mar	1	1	1	.5		
Apr	1	1	1	1		
May	1		.25	1	.25	
Jun				1	1	
Jul				1	1	.75
Aug				1	1	1
Sep				1	1	1
Oct				1	.5	1
Nov	.5	.25	.5	.75		.75
Dec	1	1	1			

Table 1: Land consumption per month

Table 1 should be read as follows: if the family chooses to farm wheat on one hectare of land, that farmland will be in use during the months of December until May and for half the month of November. The rest of the year other crops can grow on that land.

Both the yield of the land and the price of the produce are known from experience and are given in Table 2.

### Exercise 1

Construct a model that maximizes the farmers family's profit.

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<sup>1</sup>This exercise sheet was adapted from Chapter 11 A Farm Planning Problem in the AIMMS Optimization Modeling book written by Johannes Bisschop.

	yield [ton/ha]	price [€/ton]
wheat	1.50	1000
beans	1.00	2000
onions	6.00	750
cotton	1.50	3500
maize	1.75	700
tomatoes	6.00	800

Table 2: Yields and prices per crop

### Exercise 2

If you haven't done so already, think about how the land consumption constraint can be made more realistic. HINT: If we just use the given data, the resulting land consumption constraint only tells us the average consumption of the land during each month, not if the consumption is during the first or the last weeks of the month.

Of course, the family also has costs on the farm. One of them is labor. Labor is one of the major requirements for crop production. Both the farmer's family and hired workers work on the farm. In farm workers usually work different amounts of hours during the year. The labor requirements per month and per crop type are given in Table 3.

	wheat	beans	onions	cotton	maize	tomatoes
Jan	14	6	41			
Feb	4	6	40			
Mar	8	6	40	40		
Apr	8	128	155	40		
May	137		19	72	34	
Jun				16	40	
Jul				12	57	136
Aug				16	64	120
Sep				8	35	96
Oct				46	9	56
Nov	19	60	89	34		48
Dec	11	6	37			

Table 3: Labor requirements per month [hr/ha]

Outside workers can either be hired as permanent workers or as temporary workers. The fixed family labor consists of 1.5 person and costs € 4144 per person for the entire year, permanent hired labor costs € 5180 per person per year, and temporary labor costs is € 4 per hour.

The number of hours that a family member or permanent worker works each month is given in the data file.

### Exercise 3

Include the labor constraints in your model and update your objective function.

Water is the last major requirement for agricultural production. We assume that the total amount of water available to the farmer each month is restricted to 5000 m<sup>3</sup>. Moreover, there is an overall annual limit on the use of water of 50000 m<sup>3</sup>. The price of water is fixed for the entire year, and equal to € 10 per 1000 m<sup>3</sup>. The crop water requirements for the farm are given in Table 4.

	wheat	beans	onions	cotton	maize	tomatoes
Jan	0.535	0.438	0.452			
Feb	0.802	0.479	0.507			
Mar	0.556	0.505	0.640	0.197		
Apr	0.059	0.142	0.453	0.494		
May				1.047	0.303	
Jun				1.064	0.896	
Jul				1.236	1.318	0.120
Aug				0.722	0.953	0.241
Sep				0.089	0.205	0.525
Oct						0.881
Nov	0.373	0.272				0.865
Dec	0.456	0.335	0.305			

Table 4: Water requirements per month [1000 m<sup>3</sup>/ha]

#### Exercise 4

Include water requirement constraints in your model and update your objective function.

The family also feeds itself from the crops that they produce on the farm. They have found that three different bundles of produce are each sufficient to feed the family for a whole year: The first bundle contains 1.20 tons of beans, 0.15 tons of maize, and 0.25 tons of tomatoes. The second bundle contains 0.73 tons of beans, 1.50 tons of maize, and 0.25 tons of tomatoes. The third bundle contains 0.70 tons of beans, 1.00 ton of maize, and 0.75 tons of tomatoes.

#### Exercise 5

Add constraints in your model that make sure that the family does not starve. Update your objective function if necessary.