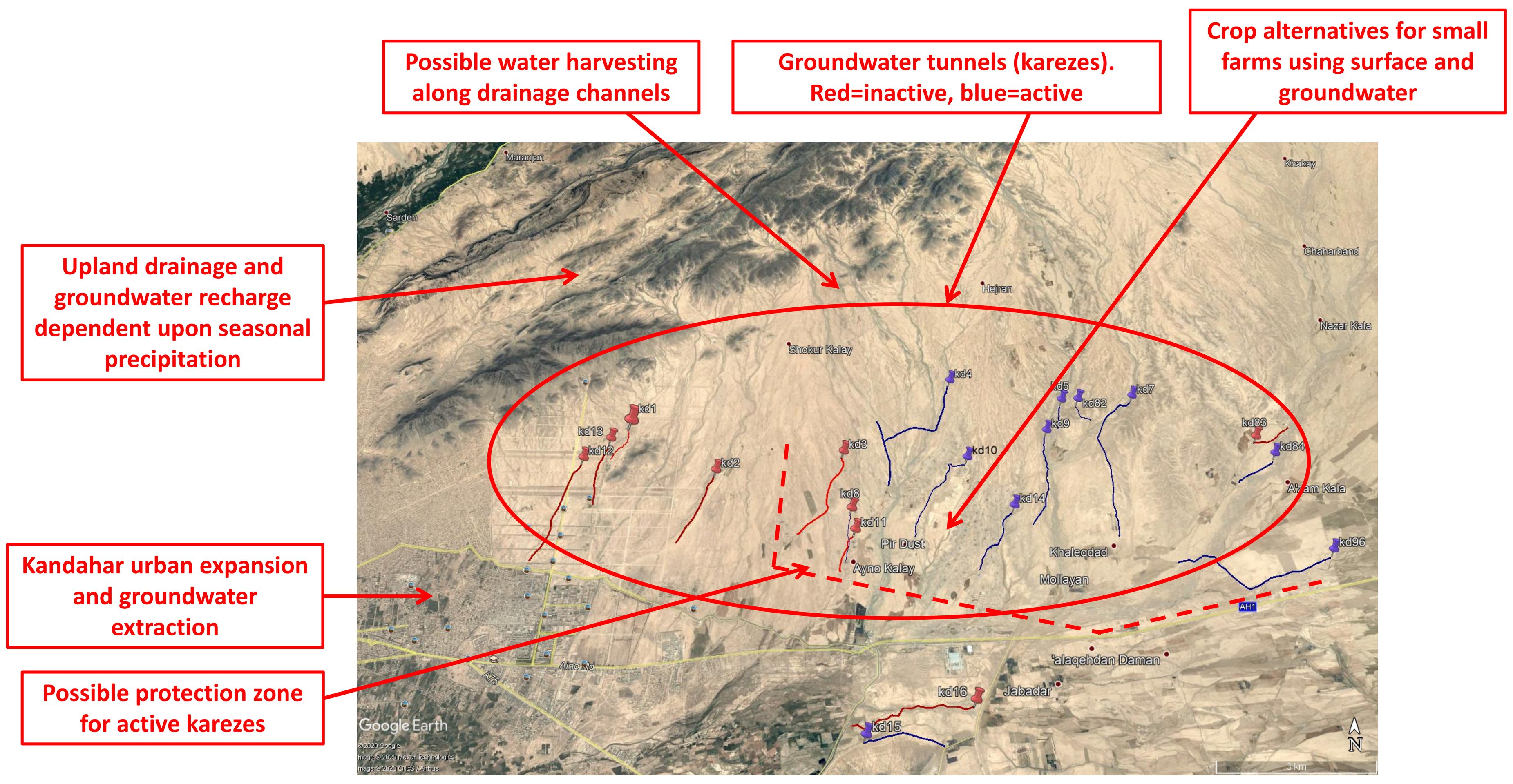
Modeling Water-Management Choices for N. Kandahar Farms

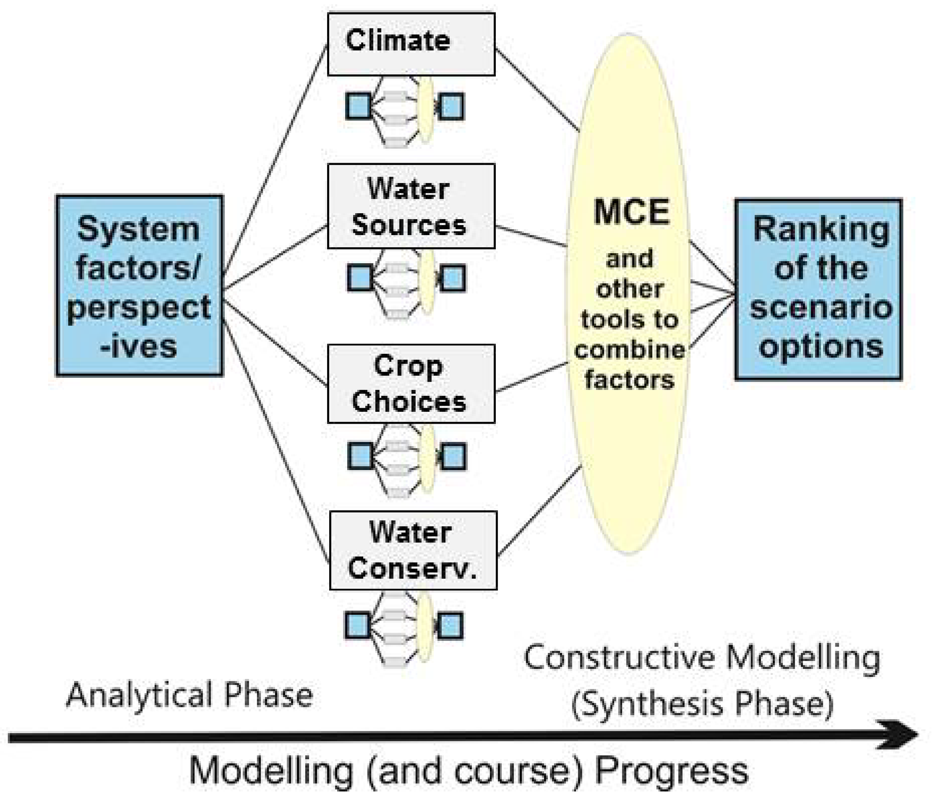
Rodney Stevens

Dept. Earth Sciences, University of Gothenburg, Sweden



BACKGROUND

This example of decision-support modeling is from a 2020 course with participants and teaching assistance from Kabul University, Afghanistan. The purpose is to illustrate useful steps in problem analysis, progressing from system characterization (analytical phase) to predictive modeling (synthesis phase), as shown in the diagram below. Simplified and assumed conditions are necessary in all modeling, but the results intend to also suggest improvements regarding both documentation and for understanding complex systems.

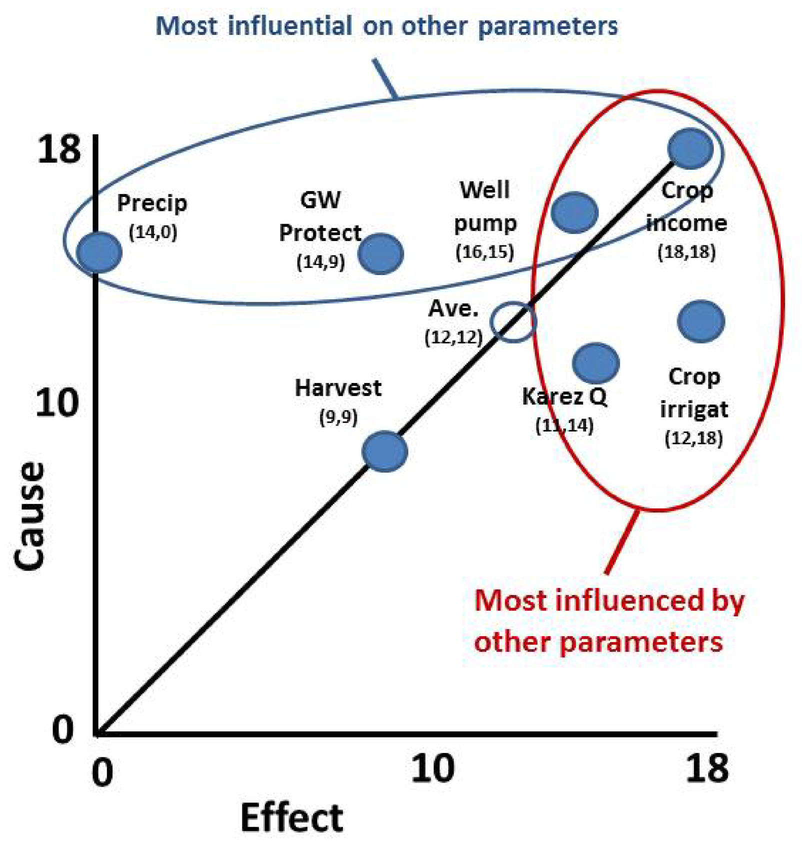


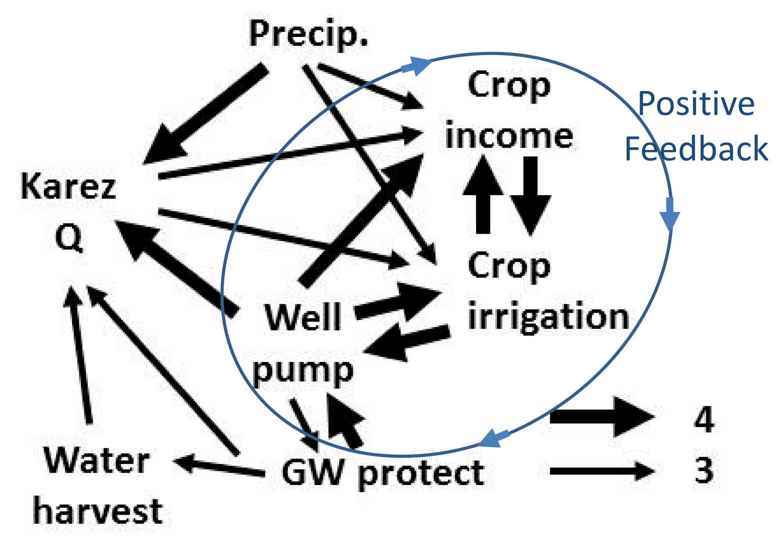
SYSTEM SKETCH

Just north of Kandahar, a rapidly growing city of about half a million, there are scattered farms that have used traditional, groundwater supply from "karez" tunnels (image above). However, well pumping and climate change in this arid region are negatively impacting upon limited groundwater resources and karez discharge (Q). The selected variables identified are used for initial characterization of the system and its dynamics in the following step.

SYSTEM STRUCTURAL ANALYSIS

Using variables related to the System Sketch, the system dynamics are evaluated from their impact relationships with the help of relative vales (0-4 scale) shown in the matrix below, based on theory, expert experience and literature information. The Cause-Effect plot and relationships diagram graphically illustrate the system, which contains mainly high-active variables influence each other. This stresses the importance of positive feed-back loops that can create system instability. For example, the relationships between pumping and crop alternatives that farmers have become increasingly limited due to the inter-system dependence, as well as the negative effects on karez discharge.





Impact Matrix

(parameter influences on each other)

	Karez Q	Precip	Well pump	Water harvest	GW protect	Crop irrigat	Crop income	Sums
Karez Q		0	2	1	2	3	3	11
Precip	4		2	1	1	3	3	14
Well pump	4	0		1	3	4	4	16
Water harvest	3	0	1		1	2	2	9
GW protect	3	0	4	3		2	2	14
Crop irrigat	1	0	4	2	1		4	12
Crop income	0	0	2	1	1	4		8
Sums	15	0	15	9	9	18	18	Ave: 84/7 = 12

Cause

Effect

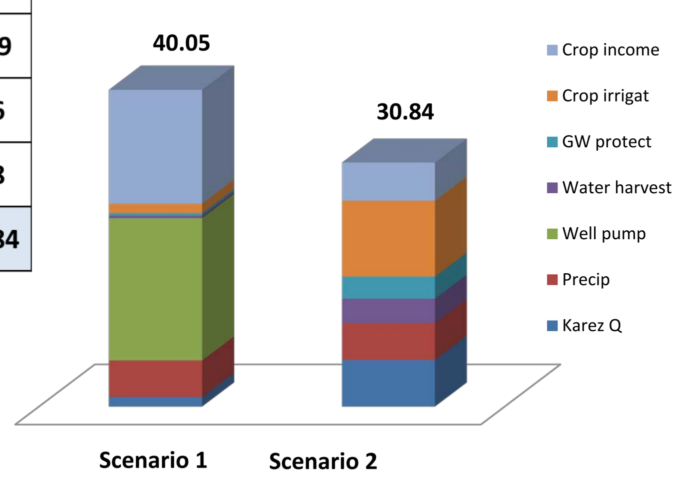
0-4 relative scale

Weighting Matrix

(relative importance for "farm economy")

	Karez Q	Precip	Well pump	Water harvest	GW protect	Crop irrigat	Crop income	Sums
Karez Q		1/3	1/5	3	1	1/3	1	5.9
Precip	3		1/3	1	3	1	1	9.3
Well pump	5	3		5	3	1	1	18
Water harvest	1/3	1	1/5		1	1/3	1/5	3.1
GW protect	1	1/3	1/3	1		1/3	1/7	3.1
Crop irrigat	3	1	1	3	3		1	12
Crop income	1	1	1	5	7	1		16

	Weights	Utility 1	Utility 2	W x U -1	W x U –2
Karez Q	5.9	0.2	1	1.18	5.9
Precip	9.3	0.5	0.5	4.65	4.65
Well pump	18	1	0	18	0
Water harvest	3.1	0.1	1	0.31	3.1
GW protect	3.1	0.1	0.9	0.31	2.79
Crop irrigat	12	0.1	0.8	1.2	9.6
Crop income	16	0.9	0.3	14.4	4.8
			sum	40.05	30.84



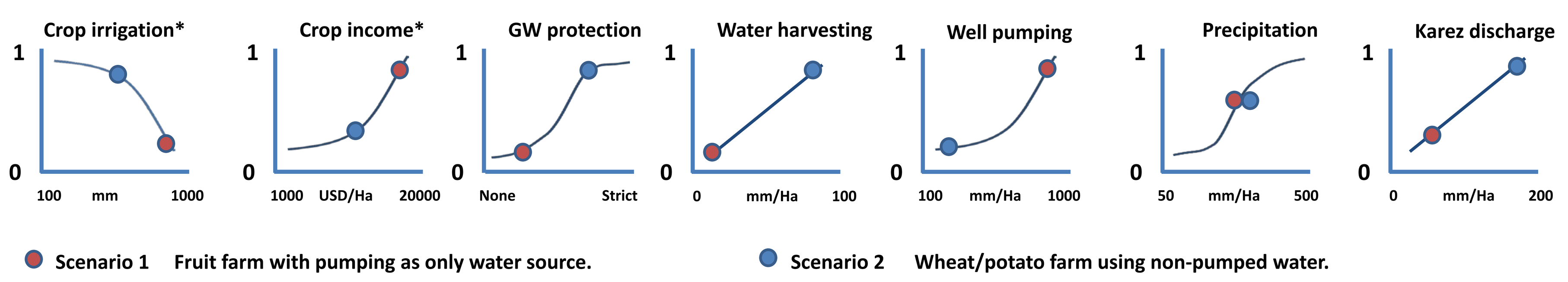
MULTI-CRITERIA EVALUATION

The conceptual analytical modeling above can also lead to predictive modeling using, for instance, MCE with the following equation:

$$\Sigma_i\, w_i \bullet u_i = \text{Total "utility"} \qquad \text{(used to rank different scenarios)}$$

For each of the parameters considered, the weights (w) are assigned according to their relative importance for the question/issue considered (pair-wise matrix comparisons) and the utility is the impact with the site-specific conditions of each parameter within the range of natural values between alternatives. The scenario with the best farm economy is evaluated for this "system" with the specified utility of various scenarios.

Utility



*Main data source: "Irrigation, Profits & Alternative Crops" www.cimicweb.org/cmo/afg

CONCLUSIONS

This structured approach to system analysis is suitable as a first, desk-top step which will ideally give focus to more detailed documentation, revision and testing. Nevertheless, the MCE scenario utilities (left) suggest that with the described conditions, pumping allows farming high-income crops that require more water, but result in better farm economy that do traditional water sources. The dominant utility contributions of pumping and crop income are perhaps interdependent and need further consideration. The positive feedback connected to pumping is unsustainable since groundwater resources are often utilized much faster than they are renewed.