River basin game – Introduction

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The aim

In this game you will play a farmer who tries to optimise his/her benefits in farming. You have enough fertile land; water is the limiting factor. Therefore you want to irrigate your crops and optimise water use such that you achieve the highest benefit from the water. The aim of this game is to achieve the highest net benefit possible so that you can maintain your family. Although your neighbour-farmers are nice people, the primary objective in the game is to **increase your personal benefit**. The game realistically illustrates various phenomena that take place when people use water in a river basin.

The setting

Depending on the number of participants, we will have one or more independent river basins. The farmers living in one river basin compete for the water in that river basin. The river basin is schematised into three compartments: upstream, midstream and downstream. In each compartment there are three to five farmers. The total number of farmers in a river basin is thus nine to fifteen. At the start of the game you can negotiate who is going to play upstream, midstream or downstream farmer. The clear advantage of upstream is that you are 'first in use'. However, the downstream advantage is that there is naturally more water.

The game consists of eight rounds. Each round corresponds to one meteorological year. Playing one round will ideally take about 15 minutes: 10 minutes for deciding your water abstraction in that round and 5 minutes for feedback from the facilitator.

At the beginning of the game, for each river basin an inventory will be made of the number of farmers and their names. As a group, please fill in the **who-is-who sheet** and hand one copy to the facilitator. And for each individual: write the name of your river basin, your location in the basin (up-, mid- or downstream) and your farmer number at the top of your **individual record sheet**.

In this game, you will have the opportunity to earn cash benefits. What you will earn depends upon your decision on how much water you abstract for irrigating your fields, and upon the decisions that others in your basin make. In particular, you need to be concerned about the total water footprint of crop production in the basin, because it may affect the hydrology of the basin and thus the availability of water and the costs of water abstraction.

The water footprint of crop production

The water footprint of farming is defined here as the volume of irrigation water that evaporates during crop production or is incorporated into the crop. In this game it is assumed that all water abstracted is evaporated or incorporated into the crop and thus lost for the basin. The total water footprint in each compartment depends on how much water you and the fellow farmers in your compartment abstract. If the water footprint in your compartment increases, water will become scarcer and the costs of abstraction will increase. Besides, be aware that the water footprint in the upper compartments will reduce the water availability downstream and thus increase downstream costs of abstraction.

Deciding on your water abstraction

In each round, you will make a decision on how much water units you abstract in that round for irrigating your fields. You write down the number of water units abstracted on your decision sheet for that round and hand that in to the facilitator. Write down the same number on the appropriate place on

the individual record sheet. For simplicity we assume here that all irrigation water will ultimately evaporate, and thus be unavailable for downstream use.

In each round, the net benefit that you obtain from the number of water units that you abstracted will be equal to the difference between (1) the gross benefit that you obtain by increased yield in that round and (2) the total cost involved in obtaining the water.

Net benefit = Gross benefit - Total cost

In each round, your abstraction will be **strictly anonymous**, known only to yourself and the facilitator. Similarly, the net benefits that you earn will be strictly private information.

Gross benefit from water abstraction

In each round, your gross benefit will depend on the number of water units that you abstracted and the benefit per unit.

Gross benefit = Units of water abstracted $\times$ Benefit per unit

The benefit per unit of water is equal throughout the game, viz. **50 euro per unit of water**.

Costs of water abstraction

In each round, the total cost of your water abstraction will be equal to the product of the number of units that you abstracted and the average cost of each unit:

Total cost = Number of units $\times$ Average unit cost

The average unit cost will increase as you and the other members of your compartment abstract more and more units. The first unit that your compartment abstracts in round 1 will cost 1 euro. The second unit that your compartment abstracts will cost 2 euro. The third unit will cost 3 euro, and so on. That is, each additional water unit will cost 1 euro more than the previous water unit abstracted.

For example, suppose that in round 1 the farmers in your compartment together abstract 100 units. The total cost of all the units abstracted will equal: 1 + 2 + 3 + . . . + 100 = 5050 euro. The average unit cost will be 5050/100 = 50.5 euro. You can easily see that the average unit cost will always be half way between the cost of the first unit abstracted and the cost of the last unit abstracted. Since the average unit cost does not only depend on how much water *you* use, but also on how much the *others* use, the facilitator will provide you with the actual average unit cost at the end of each round.

Only in round 1 the first water unit costs 1 euro. In round 2 the cost of the first unit can be higher if in the round before depletion has taken place. The rule is: if the water storage has been depleted by n water units (compared to the initial water storage in the first year), the cost of the first water unit in a next round is $1+n$ euro. Since individuals cannot know the depletion rate, the facilitator will provide you with information about the cost of the first water unit at the start of each new round.

Recording your own results

At the end of this introduction you will find your individual record sheet. During the game you will have to fill in one row for each round. At the end of each round, the facilitator gives feedback on: the total net benefit in a basin in the past round, the average cost of one unit of water in the past round (per compartment) and the cost of the first unit of water for the next round (again per compartment).

Characteristics of your river basin

In the below figure you see how the river basin is schematised into three spatial compartments. Incoming and outgoing water flows are represented by arrows.

The water balance of a compartment over one year (one round) looks as follows:

Change of water storage = Net precipitation + Inflow from upstream – Outflow – Abstraction

The outflow from a compartment in year n depends on the initial water storage in that year (i.e. the water storage at the start of the year) and the so-called 'lag time' k of the compartment:

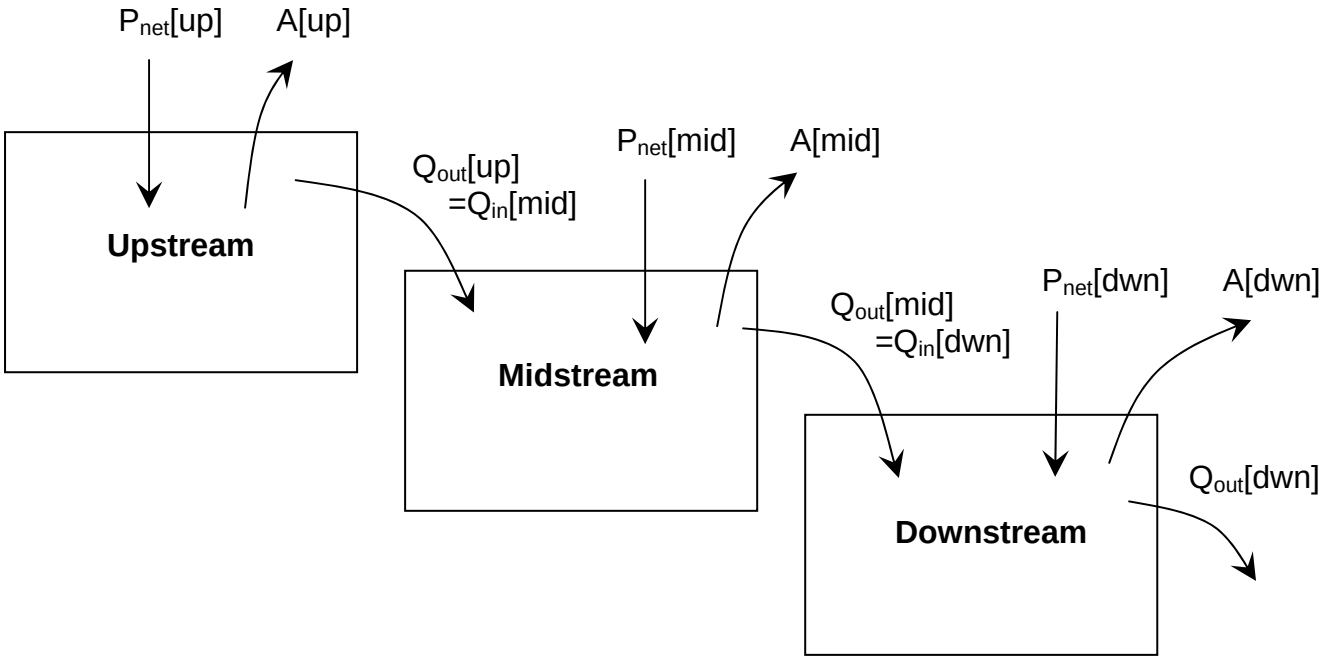
Q_{out} [year n] = S_i [year n] / k

In this game, **the value of k is 1.25 year** for all three compartments. If, for example, the water storage in a compartment is 50 at the start of a year, the outflow in that year will be 50/1.25 = 40 units.

The table below shows all relevant data for round 1. In the past, water abstractions in the basin were zero, so that in the initial situation the outflow of each compartment is equal to the net precipitation + inflow from upstream. The net precipitation will remain constant in each round, but the other variables will change if you start abstracting water for irrigation.

Variables in the game with their value for year 1:

			Values for year 1		
	Symbol	**Unit**	**Upstream**	**Midstream**	**Downstream**
Initial water storage	S_i	water units	50	75	100
Outflow	Q_{out}	water units / year	40	60	80
Net precipitation	P_{net}	water units / year	40	20	20
Inflow from upstream	Q_{in}	water units / year	-	40	60
Water abstraction	A	water units / year	?	?	?



Individual record sheet

Your name: ……
Name of your river basin: ……
Your location: upstream / midstream / downstream
Your farmer number: 1 / 2 / 3 / 4 / 5

Round 1					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit
		1			

Round 2					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 3					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 4					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 5					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 6					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 7					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Round 8					
No. of units abstracted	Gross benefit	Cost of the first unit	Average unit cost	Total cost	Net benefit

Total: Rounds 1-8					
No. of units abstracted	Gross benefit			Total cost	Net benefit