

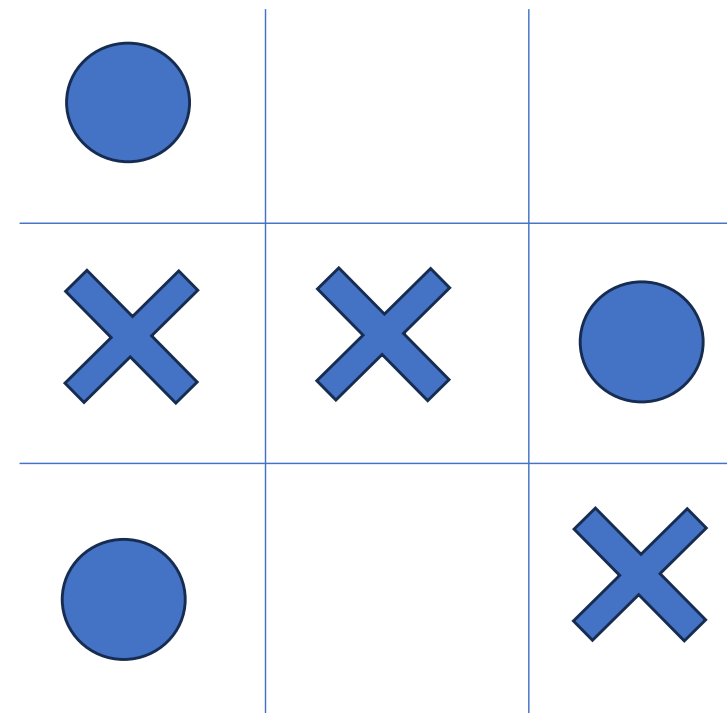
Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

Prof. P. Perona

Platform of hydraulic constructions



Lecture 8-2: Elements of game theory

Game theory approach to water conflicts

Conflict and cooperation in water problems: an overview

- Cooperation is usually measured via the number of Treaties in time among riparian States



- Conflicts is usually measured as the number of unsolved water availability problems between riparian states

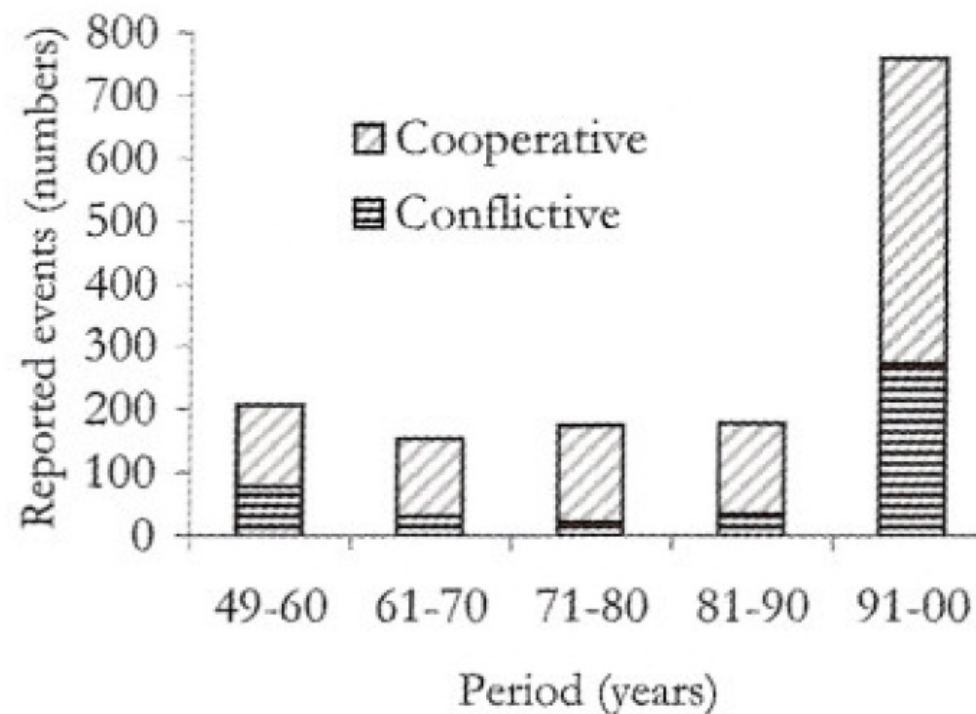


Circa 1841 conflictive and cooperative events among 263 international river basins have been recorded between 1949 and 2000.

The number of cooperation is bigger than conflicts



The claim that future wars (see Lecture 1) will be on water issues seems therefore contraddicting!



Conflictive and cooperative water events over the last 50 years.

But, a novel forcing action has begun to play an unprecedented role, which is the perception of climatic effects on resources availability

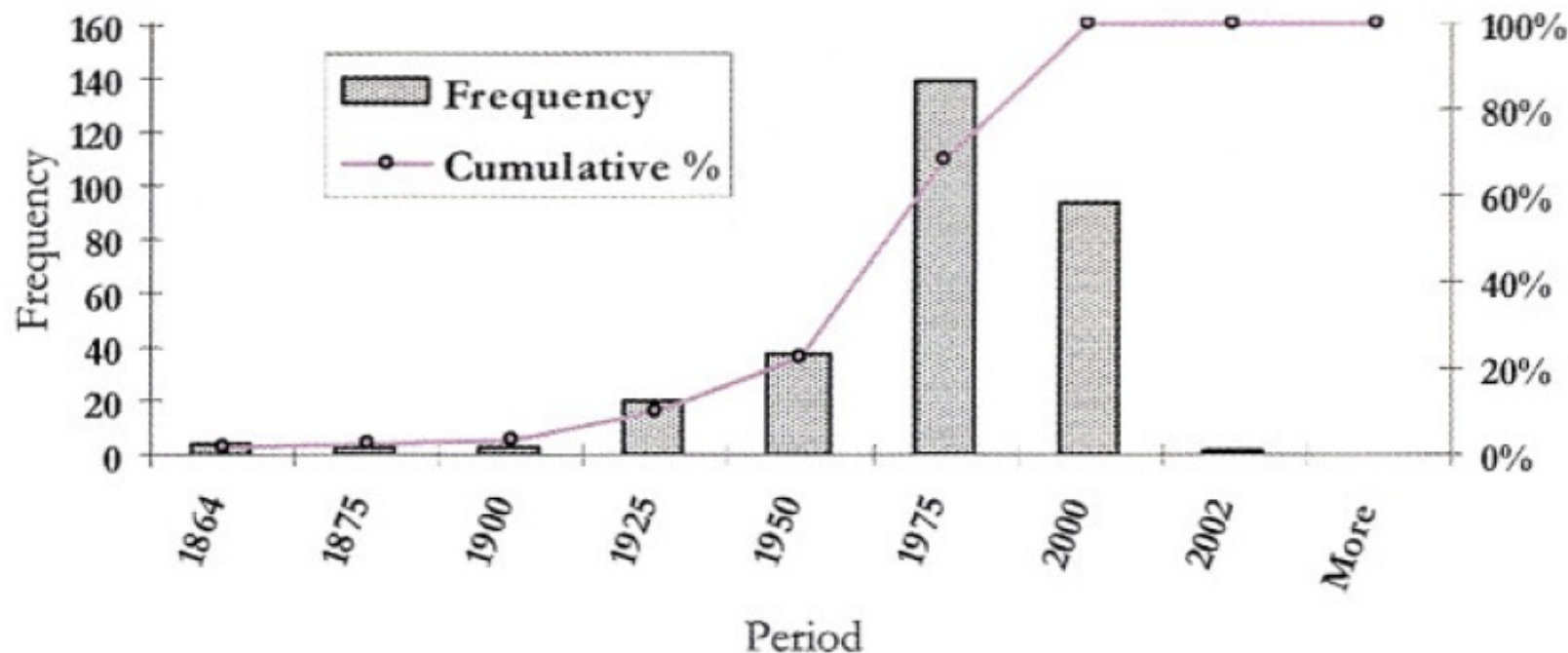


Fig. 1.7: Distribution of bilateral treaties during 1864–2002.

Please, visit <https://transboundarywaters.ceoas.oregonstate.edu/international-freshwater-treaties-database>

Example treaties for Switzerland

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI		
	Entry ID	BCCODE	BCODE	Basin Name	CCODE	Country Name	2016Update ID	2010_TREATY_Do cID	TFDDID	Unified Primary Treaty ID	Primary2 010_Trea ty_DocID	PrimaryT FDDID	DocumentName	DateSigned	Signatori es	Meets Inclusion Criteria	Governan ce Level	Binding Nature	Doc Lineage	DocType	Format	Source	Notes	LocationS igned	Region, C ontinent	PRIMAR Y_COUN TRY_SUB REGION	Treaty Basin(s)	TFDD Basin(s)	NumberP arties	Additional Comments	MinorAg reement	Referenc e to Preceden ce	Agreeme nt Purpose	GeoScop e	Issue Area	RBO	
1																																					
12	11 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	3	3	392	3	3	392	Convention between the de 8/31/1857	Austria, Badk	1	1	1	1	1	1	4	French, elect UNLS 391	States agree N.A.	Europe	Western Eur	Lake Constar	Rhine	2	N		1	2, 3	5	Infrastructure, Fundin					
66	66 RHIN_CHE	RHIN	Rhine-Meu CHE	Switzerland	16	16	16	16	16	16	Convention Between Swi 5/18/1887	Switzerland	1	1	1	1	2	9	French, elec https://lea	Switzerland Lucerne, Sw Europe	Western Eur	Rhine, Lake Rhine	2	Y	2	1, 2	5	Water Quality, Fisherie									
79	79 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	21	21	21	21	21	21	Agreement concerning the 5/18/1890	Germany, Switzerland	1	1	1	1	1	9	Missing	Listed in EEA N.A.	Europe	Western Eur	N.A.	Rhine	1	N.A.	0	0	0	N.A.							
235	235 RHON_CHE	RHON	Rhone CHE	Switzerland	51	52	242	51	52	242	Convention between France 04.10.13	Switzerland,	1	1	1	1	1	4	French, electronic	Bern, Switz Europe	Western Eur	Rhone	Rhone	1	N		1	1, 2	5	Infrastructure, Hydrop							
315	315 RHIN_CHE	RHIN	Rhine-Meu CHE	Switzerland	72	73	241	24	24	237	Treaty between the Swiss	Switzerland	1	1	1	1	1	7	French, electronic	Vienna, Aus Europe	Europe	Rhine, Lake Rhine	1	N		1	1, 3	5	Water Quantity, Infrast								
359	360 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	88	90	88	90	90	90	Convention between Germa 12.04.05	Germany, Switzerland	1	1	1	1	1	9	Missing	Listed in EEA N.A.	Europe	Western Eur	N.A.	Rhine	1	N.A.	0	0	0	N.A.							
374	375 RHIN_CHE	RHIN	Rhine-Meu CHE	Switzerland	92	96	92	92	92	92	Protocol determining the	Germany, France, Switzerland	1	1	1	1	1	7	Electronic	United Nat	They are ca	Geneva, Sw Europe	Western Eur	Rhine, betw	Rhine-Meu	2	N	2	1, 2, 3	5	Infrastructure						
375	376 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	93	96	93	96	93	96	Protocol to the Protocol det 03.01.30	Germany, France, Switzerland	1	1	1	1	1	9	Missing	Listed in EEA N.A.	Europe	Western Eur	N.A.	Rhine	2	N.A.	0	0	0	N.A.							
382	383 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	96	99	235	582	642	642	Convention for the settleme 27.08.26	France, Switz	1	1	1	1	1	7	French, electronic	Bern, Switz Europe		Rhine-Meu	Rhine-Meu	1	N		1	1, 2	5	Territorial and Border I							
384	385 RHON_CHE	RHON	Rhone CHE	Switzerland	97	100	240	97	100	240	Convention between Switzerl 19.11.30	France, Switz	1	1	1	1	1	4	French, electronic	Bern, Switz Europe		Doubs, Rh	Rhone	1	N		1	1, 2	5	Infrastructure, Hydrop							
512	513 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	140	143	398	140	143	398	Accord between Switzerl	Switzerland	1	1	1	1	1	4	French, electronic	Rome, Italy Europe		Rhine-Meu	Rhine-Meu	1	N		1	1, 2	5	Infrastructure, Hydrop							
546	547 POXX_CHE	POXX	Po CHE	Switzerland	153	158	213	153	158	213	Convention between the	Switzerland	1	1	1	1	1	4	French, electronic	Chiasso, Sw Europe		Po	Po	1	N		3	1, 3	5	Flood Management, W							
584	585 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	169	175	220	24	24	24	Treaty between the Swiss	Switzerland	1	1	1	1	1	7	French, electronic	Bern, Switz Europe		Rhine-Meu	Rhine-Meu	1	N		2	1, 2, 3	5	Infrastructure, Fundin							
644	645 POXX_CHE	POXX	Po CHE	Switzerland	188	194	210	188	194	210	Convention between Swi	Switzerland	1	1	1	1	1	4	French, electronic	Lugano, Sw Europe		Po	Po	1	N		1	2	5	Flood Management, Fu							
694	695 POXX_CHE	POXX	Po CHE	Switzerland	204	211	395	204	211	395	Convention between the	Switzerland	1	1	1	1	1	4	French, electronic	Bern, Switz Europe		Po	Po	1	N		1	1, 2	5	Infrastructure, Hydrop							
767	768 RHON_CHE	RHON	Rhone CHE	Switzerland	224	231	238	224	231	238	Convention between Swi	Switzerland	1	1	1	1	1	4	French	Paris, Franc Europe		Western Eur	Boiron, Rh	Rhone	1	N		1	3	5	Territorial and Border I						
769	770 RHON_CHE	RHON	Rhone CHE	Switzerland	225	232	239	225	232	239	Convention between Swi	Switzerland	1	1	1	1	1	4	Partial text - Annex is missing	Paris, Franc Europe		Western Eur	Rhone	Rhone	1	N		1	3	5	Territorial and Border I						
819	820 RHON_CHE	RHON	Rhone CHE	Switzerland	245	254	295	245	254	295	Convention concerning prot 16.11.62	France, Switzerland	1	1	1	1	1	4	Electronic	922 UNTS 3; 1974 UNTS 5	N.A.	Europe	Western Eur	Lake Geneva	Rhone	1	N		1	2	5	Water Quality					
825	826 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	248	257	294	248	257	294	Agreement on the Internati 29.04.63	France, Germany, Federal Republic of, Luxembourg, Netherlands, S	1	1	1	1	1	4	Electronic	994 UNTS 17	N.A.	Europe	Western Eur	Rhone	Rhone	2	N		1	2	5	Water Quality					
974	975 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	278	290	134	278	290	134	Agreement between West 30.04.66	Switzerland, German Fed. Rep., Austria	1	1	1	1	1	4	Electronic	620 UNTS 197	Berne	Europe	Western Eur	Rhone	Rhone	2	N		2, 5	4	5	Water Quantity					
985	986 RHON_CHE	RHON	Rhone CHE	Switzerland	284	298	236	284	298	236	Convention between the	Switzerland	1	1	1	1	1	4	French, electronic	Sion, Switz Europe								1	N		3	1, 2	5	Hydropower, Infrastru			
1094	1095 POXX_CHE	POXX	Po CHE	Switzerland	309	327	219	309	327	219	Exchange of letters on Ju	Switzerland	1	1	1	1	1	4	French, electronic								Western Eur	Po	Po	1	N		1	1, 3	5	Flood Management, Fu	
1151	1152 RHON_CHE	RHON	Rhone CHE	Switzerland	319	319	319	319	319	319	Exchange of letters consi	France, Switzerland	1	1	1	1	1	7	Electronic	United Nat	Treaty purs n.a	Europe	Western Eur	Lake Genev	Rhone	1	In the form N		2	3	5	Water Quality					
1165	1166 DANU_CHE	DANU	Danube CHE	Switzerland	325	346	259	325	346	259	Convention concerning the 20.04.72	Italy, Switzerland	1	1	1	1	1	4	Electronic	957 UNTS 279; www.faoe	Rome	Europe	Western Eur	Lake Maggio Danube, Po,	1	Concerns pro N		1	2	3	Water Quality						
1167	1168 POXX_CHE	POXX	Po CHE	Switzerland	325	346	259	325	346	259	Convention concerning the 20.04.72	Italy, Switzerland	1	1	1	1	1	4	Electronic	957 UNTS 279; www.faoe	Rome	Europe	Western Eur	Lake Maggio Danube, Po,	1	Concerns pro N		1	2	3	Water Quality						
1169	1170 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	325	346	259	325	346	259	Convention concerning the 20.04.72	Italy, Switzerland	1	1	1	1	1	4	Electronic	957 UNTS 279; www.faoe	Rome	Europe	Western Eur	Lake Maggio Danube, Po,	1	Concerns pro N		1	2	3	Water Quality						
1175	1176 POXX_CHE	POXX	Po CHE	Switzerland	327	348	388	327	348	388	Convention between Swi	Switzerland	1	1	1	1	1	4	French, electronic	Bern, Switz Europe								1	N		2	2, 3	5	Infrastructure, Fundin			
1270	1271 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	360	385	300	248	257	294	Convention on the protectio 03.12.76	France, Germany, Federal Republic of, Luxembourg, Netherlands, S	1	1	1	1	1	7	Electronic	1404 UNTS 90; 16 ILM 242 Bonn	N.A.	Europe	Western Eur	Rhone	Rhone-Meuse	2	N		2	2	1	5	Water Quality				
1275	1276 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	361	386	340	248	257	294	Convention on the protectio 03.12.76	European Economic Community, France, Germany, Federal Republi	1	1	1	1	1	7	Electronic	1124 UNTS 405; www.fao	N.A.	Europe	Western Eur	Rhone	Rhone-Meuse	2	N		2	2	4	Water Quality					
1284	1285 RHON_CHE	RHON	Rhone CHE	Switzerland	362	388	293	362	388	293	Agreement concerning the 05.05.77	France, Switzerland	1	1	1	1	1	4	Electronic	1080 UNTS 159	N.A.	Europe	Western Eur	Lake Geneva	Rhone	1	Establishes p		1	3	5	Water Quality					
1357	1360 RHON_CHE	RHON	Rhone CHE	Switzerland	387	417	191	245	254	295	Decree number 81-1130	France, Swi	1	1	1	1	1	7	French, electronic	Bern, Switz Europe		Western Eur	Lake Lemann	Rhone	1	N		1	1	5	Environment, Funding						
1444	1449 UNKN_CHE	UNKN	Unknown CHE	Switzerland	411	450	411	450	450	450	Convention between the	Italy, Switz	1	1	1	1	1	3	French, electronic	Rome, Italy Europe		Western Eur	Lake Maggi	Po	1	N		1	2, 3	5	Fisheries, Environment						
1452	1457 RHON_CHE	RHON	Rhone CHE	Switzerland	415	454	415	454	454	454	Convention instituting the 19.02.87	France, Switzerland	1	1	1	1	1	2	French	http://faole	http://faolex	N.A.	Europe	Western Eur	Lake Geneva	Rhone	1	N.A.	0	0	0	N.A.					
1469	1474 RHON_CHE	RHON	Rhone CHE	Switzerland	418	457	355	418	457	355	Convention introducing	Le canton c	1	1	1	1	1	2	French, electronic	Bern, Switz Europe		Western Eur	Rhone	Rhone	1	N		1	1, 2	5	Infrastructure, Environ						
1528	1533 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	440	481	337	440	481	337	Agreement between the go 17.05.90	Land Baden Wurttemberg, Switzerland	1	1	1	1	1	9	Missing								1	No commissi		0	0	0	N.A.				
1564	1569 RHON_CHE	RHON	Rhone CHE	Switzerland	450	481	337	450	481	337	Implementing regulatio	French Republic, Swiss Federal Council	1	1	1	1	1	4	Electronic	Most of th	Paris, Franc Europe		Western Eur	Doubs	Rhone	1	Y		2, 3	1	5	Fisheries, Environment					
1601	1606 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	452	496	335	360	385	300	Additional protocol to the 25.09.91	France, Germany, Federal Republic of, Luxembourg, Netherlands, S	1	1	1	1	1	7	Electronic	1994 UNTS 372	Bonn	Europe	Western Eur	Rhone	Rhone	2	N		2	1	5	Water Quality					
1660	1661 RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	452	496	335	360	385	300	Additional protocol to the 25.09.91	France, Germany, Federal Republic of, Luxembourg, Netherlands, S	1	1	1	1	1	7	Electronic	1994 UNTS 372	Bonn	Europe	Western Eur	Rhone	Rhone	2	N		2	1	5	Water Quality					

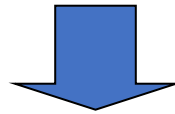
Full Treaty Database

Information

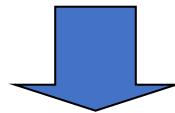
Sheet1

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It has been shown (Dinar et al 2005) that often is water scarcity to drive the process of cooperation among riparians to rivers that share more riparian states

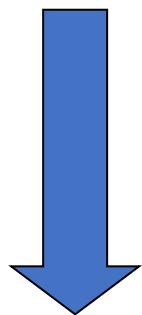


Strategies begin to appear in order to maximize benefits of the involved riparian states

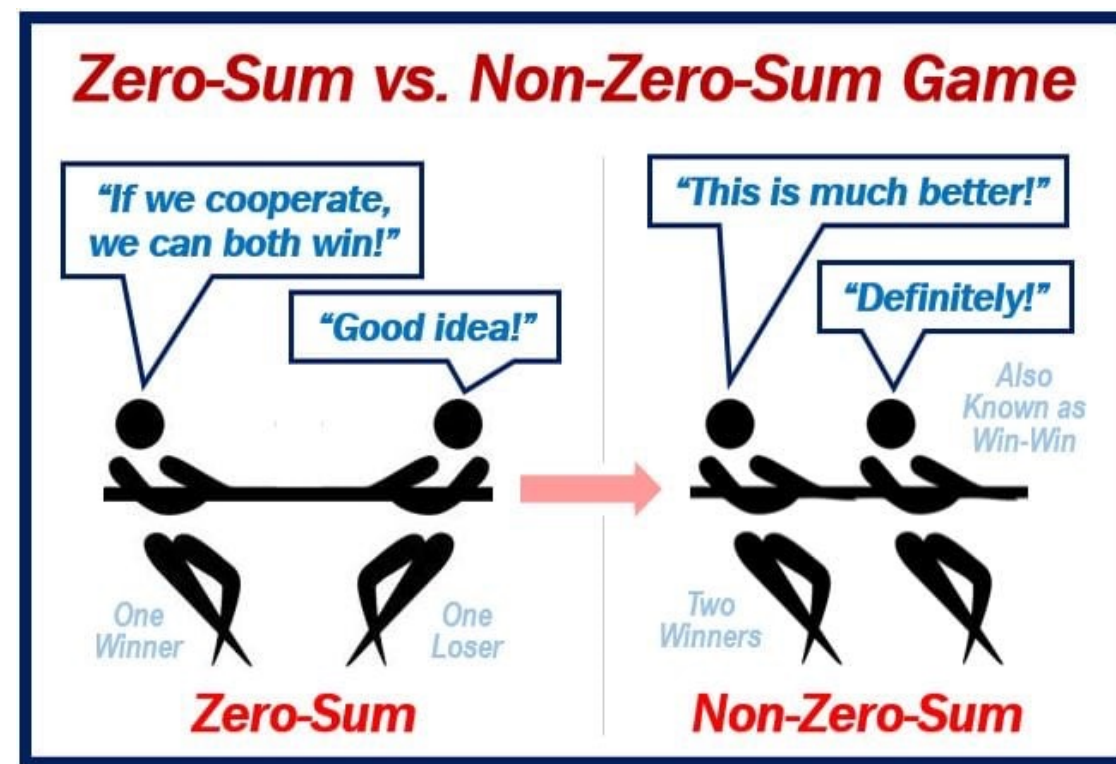


Objective functions are therefore discontinuous and classic optimization tools are not adequate!

The paradox is that a common problem (e.g., water scarcity) may lead also to a common solution which may be suitable to all involved riparian states and modify win situation scenarios

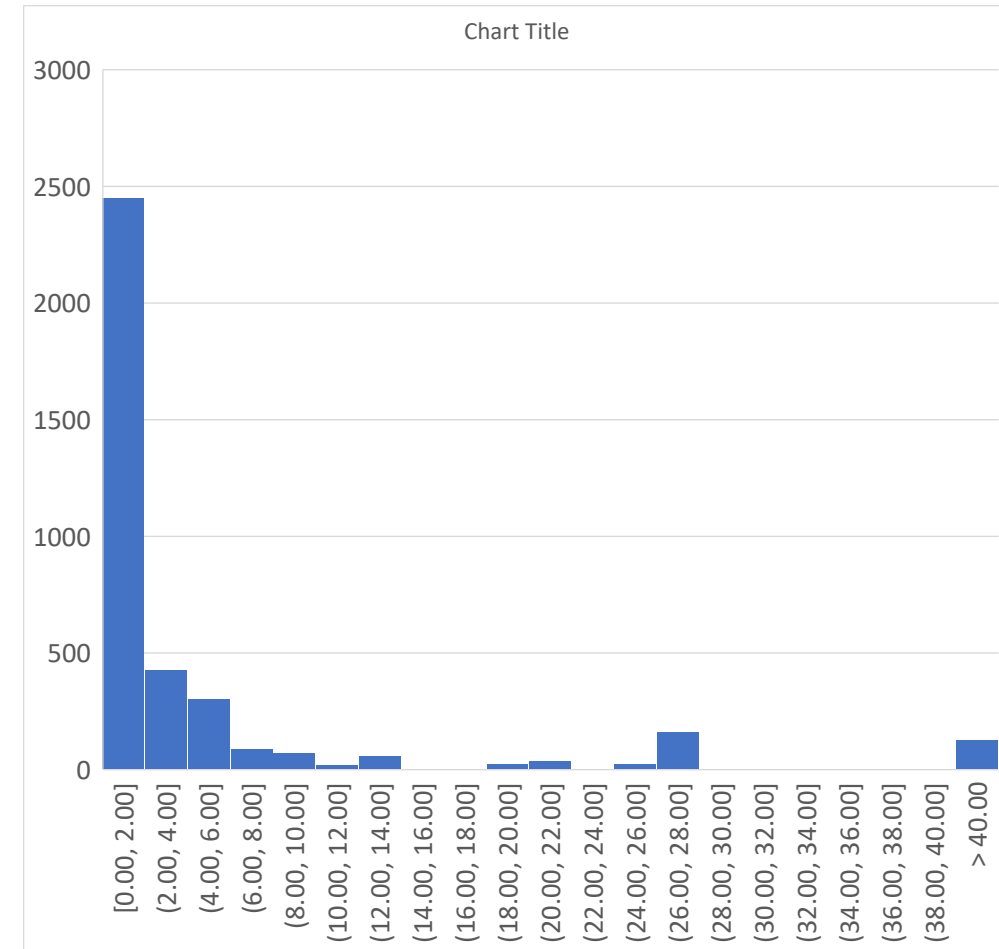


GAME THEORY
(Zero sum vs Non-zero sum games)



Why game theory in WRM?

- 1) Water-related conflicts usually involve a limited number of stakeholders (players) that are interrelated to each other
- 2) There is a greater scope for strategic behaviour among players in water related conflicts
- 3) The level of externalities associated with water utilization is a big incentive for cooperation



Statistics from all treaties, sourced from
<https://transboundarywaters.ceoas.oregonstate.edu/international-freshwater-treaties-database>

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Entry ID	BCCODE	BCODE	Basin Name	CCODE	Country_ Name	2016Update ID	2010_TREATY_Do cID	TFDDID	Unified Primary Treaty ID	Primary2010_Treaty_DocID	PrimaryT FDDID	DocumentName	DateSigned	Signatories	Meets Inclusion Criteria	Governance Level	Binding Nature
1																		
12	11	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	3	3	392	3	3	392	Convention between the delegates of the riparian states of Lake Constance: Bade, Bavaria, Austria, Switzerland and Wurtemberg, concerning the regula	8/31/1857	Austria, Bade, Bavaria, Switzerland, Wurtemberg	1	1	
66	66	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	16	16		16			Convention between Switzerland, The Grand Duchy Of Baden, And Alsace-Lorraine, Establishing Uniform Provisions On Fishing In The Rh	5/18/1887	Switzerland, Grand Duchy of Baden, Alsace-Lorraine	1	1	
79	79	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	21	21		21			Agreement concerning the Hydropower station at Rheinfelden between Germany and Switzerland	5/18/1890	Germany, Switzerland			
235	235	RHON_CHE	RHON	Rhone	CHE	Switzerland	51	52	242	51	52	242	Convention between France and Switzerland for the management of the hydraulic power of the Rhone between the planned factory of La Plaine and a po	04.10.13	Switzerland, France	1	1	
315	315	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	72	73	241	24	24	237	Treaty between the Swiss Confederation and the Republic of Austria for the adjustment of the Rhine from L'Ille to Lake Constance	02.11.25	Switzerland, Austria	1	1	
359	360	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	88	90		88	90		Convention between Germany and Switzerland regarding regulation of the Rhine between Strasbourg-Kehl and Istein	12.04.05	Germany, Switzerland			
374	375	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	92			92			Protocol determining the methods of technical and administrative co-operation between germany, france, and switzerland in the work fo	18.12.29	Germany, France, Switzerland			
375	376	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	93	96			0		Protocol to the Protocol determining the methods of Technical and Administrative Co-operation between Germany, France and Switzerland in the work	03.01.30	Germany, France, Switzerland			
382	383	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	96	99	235	582	642		Convention for the settlement of relations between Switzerland and France on the subject of certain clauses of the legal regime of the future derivation	27.08.26	France, Switzerland	1	1	
384	385	RHON_CHE	RHON	Rhone	CHE	Switzerland	97	100	240	97	100	240	Convention between Switzerland and France on the subject of the concession of the Chatelat waterfall	19.11.30	France, Switzerland	1	1	
512	513	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	140	143	398	140	143	398	Accord between Switzerland and Italy about concessions of the hydraulic forces of the Reno di Lei river	18.06.49	Switzerland, Italy	1	1	
546	547	POXX_CHE	POXX	Po	CHE	Switzerland	153	158	213	153	158	213	Convention between the Swiss Confederation and the Italian Republic concerning the correction of the Roggia Molinara canal (commune	05.04.51	Switzerland, Italy	1	1	
584	585	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	169	175	220	24	24	237	Treaty between the Swiss Confederation and the Republic of Austria for the regularization of the Rhin from the opening of the Ile of Lake	10.04.54	Switzerland, Austria	1	1	
644	645	POXX_CHE	POXX	Po	CHE	Switzerland	188	194	210	188	194	210	Convention between Switzerland and Italy about the regularization of Lake Lugano	17.09.55	Switzerland, Italy	1	1	
694	695	POXX_CHE	POXX	Po	CHE	Switzerland	204	211	395	204	211	395	Convention between the Swiss Confederation and the Republic of Italy about the utilisation of the hydraulic force of the Spol	27.05.57	Switzerland, Italy	1	1	
767	768	RHON_CHE	RHON	Rhone	CHE	Switzerland	224	231	238	224	231	238	Convention between Switzerland and France concerning the correction of the Boiron stream	03.12.59	Switzerland, France	1	1	
769	770	RHON_CHE	RHON	Rhone	CHE	Switzerland	225	232	239	225	232	239	Convention between Switzerland and France about a correction to the Hermance	03.12.59	Switzerland, France	1	1	
819	820	RHON_CHE	RHON	Rhone	CHE	Switzerland	245	254	295	245	254	295	Convention concerning protection of the waters of Lake Geneva against pollution	16.11.62	France, Switzerland			
825	826	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	248	257	294	248	257	294	Agreement on the International Commision for the protection of the Rhine against pollution	29.04.63	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation			
974	975	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	278	290	134	278	290	134	Agreement between West Germany, Austria, and Switzerland relating to the withdrawal of water from Lake Constance	30.04.66	Switzerland, German Fed. Rep., Austria			
985	986	RHON_CHE	RHON	Rhone	CHE	Switzerland	284	298	236	284	298		Convention between the Swiss Confederation and the Republic of France about the hydroelectric layout of the Emossou	23.08.63	Switzerland, France	1	1	
1094	1095	POXX_CHE	POXX	Po	CHE	Switzerland	309	327	219	309	327		Exchange of letters on June 15, 1970 between Switzerland and Italy concerning the organization of the water flow of the Breggia on the R	15.06.70	Switzerland, Italy	1	1	
1151	1152	RHON_CHE	RHON	Rhone	CHE	Switzerland	319			319			Exchange of letters constituting an agreement between france and switzerland on the implementation of the convention of 16 november	21.10.71	France, Switzerland			
1165	1166	DANU_CHE	DANU	Danube	CHE	Switzerland	325	346	259	325	346	259	Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	20.04.72	Italy, Switzerland			
1167	1168	POXX_CHE	POXX	Po	CHE	Switzerland	325	346	259	325	346	259	Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	20.04.72	Italy, Switzerland			
1169	1170	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	325	346	259	325	346	259	Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	20.04.72	Italy, Switzerland			
1175	1176	POXX_CHE	POXX	Po	CHE	Switzerland	327	348	388	327	348		Convention between Switzerland and Italy about the layout of the hydraulic flow of the Breggia at the Italian-Swiss border	23.06.72	Switzerland, Italy	1	1	
1270	1271	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	360	385	300	248	257	294	Convention on the protection of the Rhine against pollution by chlorides (with annexes and exchanges of letters dated 1983), concluded at Bonn	03.12.76	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation			
1275	1276	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	361	386	340	248	257	294	Convention on the protection of the Rhine against chemical pollution	03.12.76	European Economic Community, France, Germany, Federal Republic of, Luxembourg, Netherlands, Switzerland			
1284	1285	RHON_CHE	RHON	Rhone	CHE	Switzerland	362	388	293	362	388	293	Agreement concerning the activities of agencies for the control of accidental water pollution by hydrocarbones or other substances capable of contaminat	05.05.77	France, Switzerland			
1357	1360	RHON_CHE	RHON	Rhone	CHE	Switzerland	387	417	191	245	254	295	Decree number 81-1130 from December 15, 1981, about an accord between the Government of the Republic of France and the Swiss Fe	20.11.80	France, Switzerland	1	1	
1444	1449	UNKN_CHE	UNKN	Unknown	CHE	Switzerland	411	450		411	450		Convention between the Swiss Confederation and the Republic of Italy about fisheries within Italian-Swiss waters	19.03.86	Italy, Switzerland	1	1	
1452	1457	RHON_CHE	RHON	Rhone	CHE	Switzerland	415	454		415	454		Convention instituting the Council of Lake Geneva	19.02.87	France, Switzerland			
1469	1474	RHON_CHE	RHON	Rhone	CHE	Switzerland	418	457	355	418	457		Convention introducing the Council of Leman, Lausanne, on February 19, 1987, and the exchange of letters from June 10, 1987	10.06.87	Le canton de Vaud, Le canton de Valais, Le canton de Geneve, Le departement de l'ain, Le departement de la haute-savoie	1	1	
1528	1533	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	440	481	337	440	481		Agreement between the government of the Land Badenwurttemberg and the Swiss Federal Council concerning the joint construction and operation of a	17.05.90	Land Baden Wurttenberg, Switzerland			
1564	1569	RHON_CHE	RHON	Rhone	CHE	Switzerland	450						Implementing regulations of the agreement between the government of the French Republic and the Swiss Federal Council concerning th	29.07.91	French Republic, Swiss Federal Council			
1601	1606	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	452	496	335	360	385	300	Additional protocol to the convention on the protection of the Rhine against pollution from chlorides	25.09.91	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation			
1680	1685	GNRL_CHE	GNRL	General	CHE	Switzerland	461						Convention on the protection and use of transboundary watercourses and international lakes	17.03.92	Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Cameroon, Chad, Croatia, Czech Republic, D	1	1	
1878	1883	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	516	567	256	516	567		Convention relative to the collection, deposit, and the reception of trash occuring during navigation of the Rhine and the interior	09.09.96	Belgium, Germany, Luxembourg, Netherlands, Switzerland, France	1	1	
1899	1904	RHON_CHE	RHON	Rhone	CHE	Switzerland	526	579		526	579		Règlement sur la manoeuvre de l'ouvrage de régularisation du niveau du lac Léman à Genève	17.09.97	Switzerland			
1921	1926	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	535	589	193	248	257	294	Convention on the protection of the Rhine	22.01.98	France, Luxembourg, German Fed. Rep., Switzerland, Netherlands, European Union			
1953	1958	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	548	602		248	257	294	Convention on the Protection of the Rhine	12.04.99	Federal Republic of Germany, French Republic, Grand Duchy of Luxembourg, Kingdom of the Netherlands, Swiss Confederation, European Community			
2132	2137	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	582		642		582	642	Agreement concerning the scheme for the kembs lateral canal, with proces-verbal	10.05.22	Germany, France, Switzerland			
2188	2193	RHON_CHE	RHON	Rhone	CHE	Switzerland	595	1004		245	254	191	Exchange of notes constituting an agreement amending the agreement between the government of the French Republic and the Swiss F	19.09.95	France, Switzerland			
2292	2297	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	630	1077		0			Revised convention relating to the navigation of the Rhine	10/17/1868	France, Grand Duchy of Baden, Bavaria, Grand Duchy of Hessen, Netherlands, Prussia			
2296	2301	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	631	1078		0			Convention regulating the relations with regard to certain clauses of the legal regime of the future Kembs derivation, with additional prot	27.08.26	Swiss Federal Council, French Republic			
2495	2500	GRND_CHE	GRND	Groundwat	CHE	Switzerland	677			677			Convention on the protection, utilization, recharge, and monitoring of the Franco-Swiss genevois Aquifer	18.12.07	France: Communities of Annemassienne and Genevois rural district and rural district of Viry; Switzerland: Republic and Canton of Geneva			
2596	2601	RHIN_CHE	RHIN	Rhine-Meuse	CHE	Switzerland	701			701			Convention between Germany and Switzerland regarding the regulation of the Rhine between Strasbourg-Kehl and Istein. Signed at Berne, March 28, 19	28.03.29	Swiss Confederation, German Reich			
2687	2690	GRND_CHE	GRND	Groundwat	CHE	Switzerland	727			727			Charter on Groundwater Management	00/00/1989	UNECE member states			
2772	2775	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	743			743			Protocol determining the methods of technical and administrative cooperation between Germany, France and Switzerland in the work fo	18.12.29	Germany, France, and Switzerland			
2962	2965	DANU_CHE	DANU	Danube	CHE	Switzerland	775			775			Treaty of Peace with Germany (Treaty of Versailles)	28.06.19	United States, United Kingdom, Dominion of Canada, Commonwealth of Australia, Union of South Africa, Commonwealth of New Zealand, India, France, Italy			
2984	2987	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	775			775			Treaty of Peace with Germany (Treaty of Versailles)	28.06.19	United States, United Kingdom, Dominion of Canada, Commonwealth of Australia, Union of South Africa, Commonwealth of New Zealand, India, France, Italy			
3408	3411	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	849			630			Convention signed at Strasbourg on 20 November 1963, amending the revised Convention for Rhine Navigation signed at Mannheim on	20.11.63	Federal Republic of Germany, Kingdom of Belgium, French Republic, The United Kingdom of Great Britain and Northern Ireland, Kingdom of the Netherlands			
3422	3425	GRND_CHE	GRND	Groundwat	CHE	Switzerland	852						Agreement on the protection, utilization, and recharge of the Franco-Swiss Geneveise Aquifer	09.06.77	State Council of the Republic and the Canton of Geneva, Prefect of Haute-Savoie			
3457	3460	RHIN_CHE	RHIN	Rhine-Meu	CHE	Switzerland	858			248			Supplementary agreement to the agreement concluded in Bern on April 29, 1963 about the International Commission for the Protection	03.12.76	Federal Republic of Germany, French Republic, Grand Duchy of Luxembourg, Kingdom of the Netherlands, Swiss Confederation, European Economic Comm			

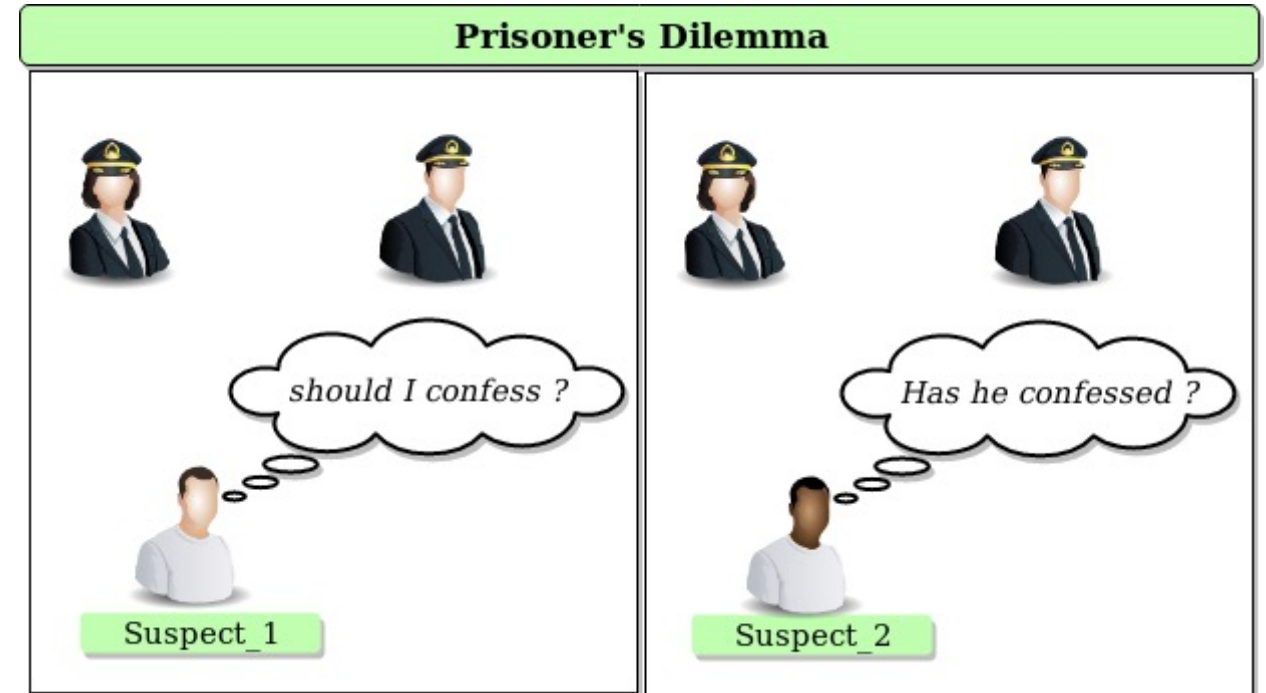
The foundation of strategic analysis

- In a social setting, we have to assume common knowledge, i.e.
 - Each player is rational
 - Each player knows that
 - Each player knows that each player knows that
 - And so on and so forth



Prisoner's dilemma

Two suspects are arrested by the police. The police has insufficient evidence for a conviction, and, having separated both prisoners, visit each of them to offer the same deal. If one testifies (defects from the other) for the prosecution against the other and the other remains silent (cooperates with the other), the betrayer goes free and the silent accomplice receives the full 10-year sentence. If both remain silent, both prisoners are sentenced to only six months in jail for a minor charge. If each betrays the other, each receives a three-year sentence. Each prisoner must choose to betray the other or to remain silent. Each one is assured that the other would not know about the betrayal before the end of the investigation. How should the prisoners act?



Payoff matrix: cooperative vs non-cooperative solutions

		Prisoner B Stays Silent	Prisoner B Betrays
Cooperative solution	Prisoner A Stays Silent	Each serves 6 months	Prisoner A: 10 years Prisoner B: goes free
	Prisoner A Betrays	Prisoner A: goes free Prisoner B: 10 years	Each serves 3 years
		Non-Cooperative solution	

Example PD payoff matrix

	Cooperate	Defect
Cooperate	3, 3	0, 5
Defect	5, 0	1, 1

Win-lose terminology

	Cooperate	Defect
Cooperate	win-win	lose much-win much
Defect	win much-lose much	lose-lose

Nash equilibrium

A Nash equilibrium is a set of strategies which represents mutual best responses to the other strategies. In other words, if every player is playing their part of a Nash equilibrium, no player has an incentive to unilaterally change his or her strategy. Considering only situations where players play a single strategy without randomizing (a pure strategy) a game can have any number of Nash equilibria

Example PD payoff matrix

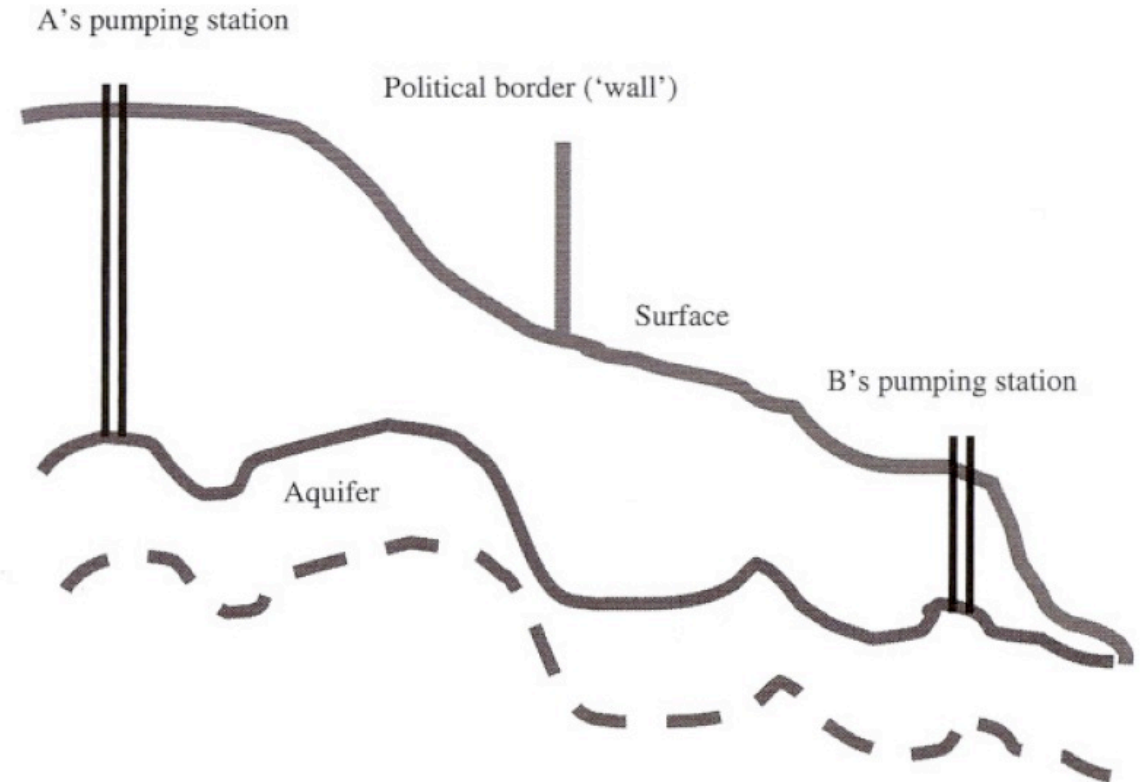
	Cooperate	Defect
Cooperate	3, 3	0, 5
Defect	5, 0	1, 1

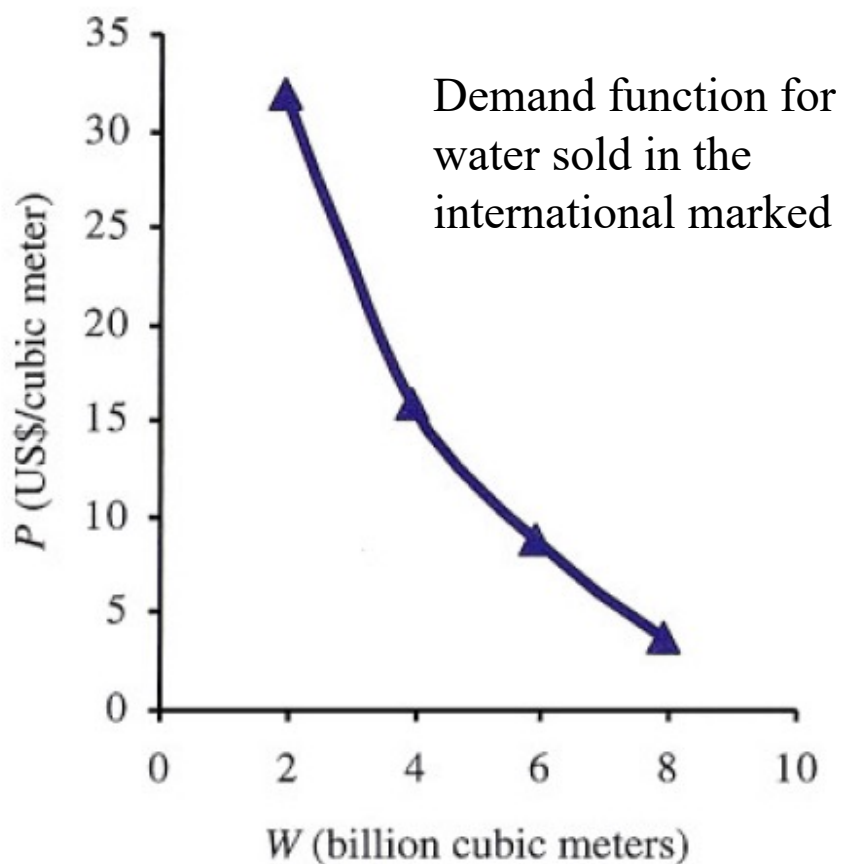
Nash equilibrium,
or lose-lose
situation

Example of application to WRM

Two countries A and B are withdrawing water from a common aquifer as shown in the figure aside. The political border sets the pumping stations of country A at a higher elevation than that of country B, for which pumping is therefore cheaper. Both countries sell the water to a common market and therefore receive the same benefits. The price of water depends on the total quantity being sold.

What is the payoff matrix and can this help to find out a cooperative solution?





Cost for pumping: e.g.
 $C_A = 0.6 \text{ \$/m}^3$

Table 5.1: The demand schedule for water in the international market.

P (US\$/m ³)	W (billion m ³)
32	2
16	4
9	6
4	8

Benefits are the same for both Countries, but costs are clearly different!
 E.g., A pumps from a deeper aquifer than that where B does

$$C_B = 0.2 \text{ \$/m}^3$$

The payoff matrix: build by using a cost-benefits approach

A pumps 2 and B pumps 2, Total water is 4, sold for 16\$/m³

Return for A is $16 \cdot (2) - 2 \cdot (0.6) = 30.8$

Return for B is $16 \cdot (2) - 2 \cdot (0.2) = 31.8$

A pumps 2 and B pumps 4, Total water is 6, sold for 9\$/m³

Return for A is $9 \cdot (2) - 2 \cdot (0.6) = 16.8$

Return for B is $9 \cdot (4) - 4 \cdot (0.2) = 35.2$

A pumps 4 and B pumps 2, Total water is 6, sold for 9\$/m³

Return for A is $9 \cdot (4) - 4 \cdot (0.6) = 33.6$

Return for B is $9 \cdot (2) - 2 \cdot (0.2) = 17.6$

A pumps 4 and B pumps 4, Total water is 8, sold for 4\$/m³

Return for A is $4 \cdot (4) - 4 \cdot (0.6) = 13.6$

Return for B is $4 \cdot (4) - 4 \cdot (0.2) = 15.2$

Simple, but very interesting result!

		Country B	
		Water pumping strategy (billions of m ³ /year)	
		2	4
Country A	Water pumping strategy (billions of m ³ /year)	<div>30.8</div> <div>31.6</div>	<div>16.8</div> <div>35.2</div>
	4	<div>33.6</div> <div>17.6</div>	<div>13.6</div> <div>15.2</div>

Fig. 5.3: The **strategy/payoff** matrix of the water pumping **prisoner's dilemma** game.

Note: The values to the upper left of each cell are of country A and those to the lower right of each cell are of country B.

- Non-cooperative solution at Nash equilibrium (marked is dumped)
- Cooperative solution (communication between players)

Conclusions

Transboundary water problems set generally on a complex background (historical, geographical, physical inequalities).

Strategic rules may lead to non-smooth payoff results (discontinuous objective function), which preclude the use of classic optimization

One needs to account for possible cooperation among stakeholders and related improvement toward an equilibrium solution

Game theory is often preferable cause defining payoff matrixes is often easier

Despite simple, such games help explaining why cooperation can improve the individual payoff level of typical PD non-cooperative solutions