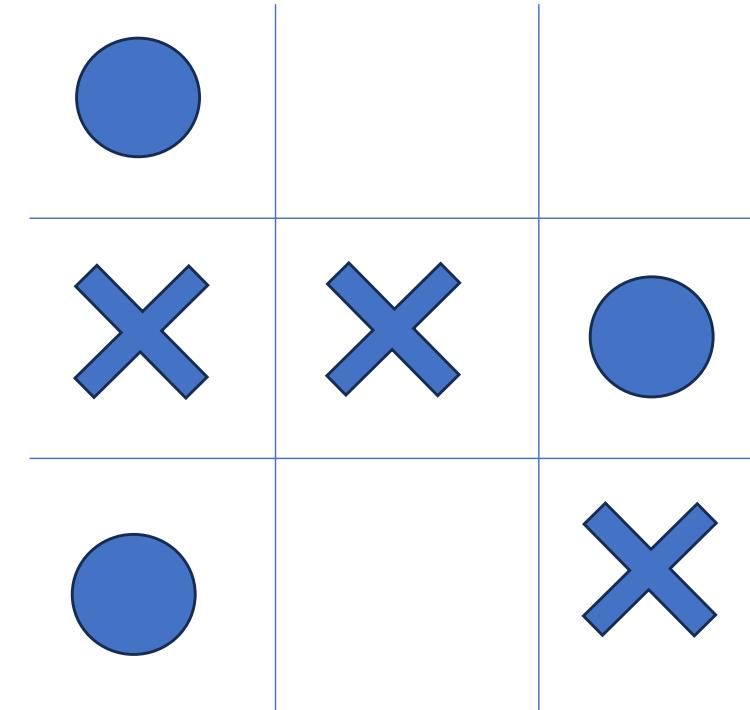


Water Resources Engineering and Management

(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

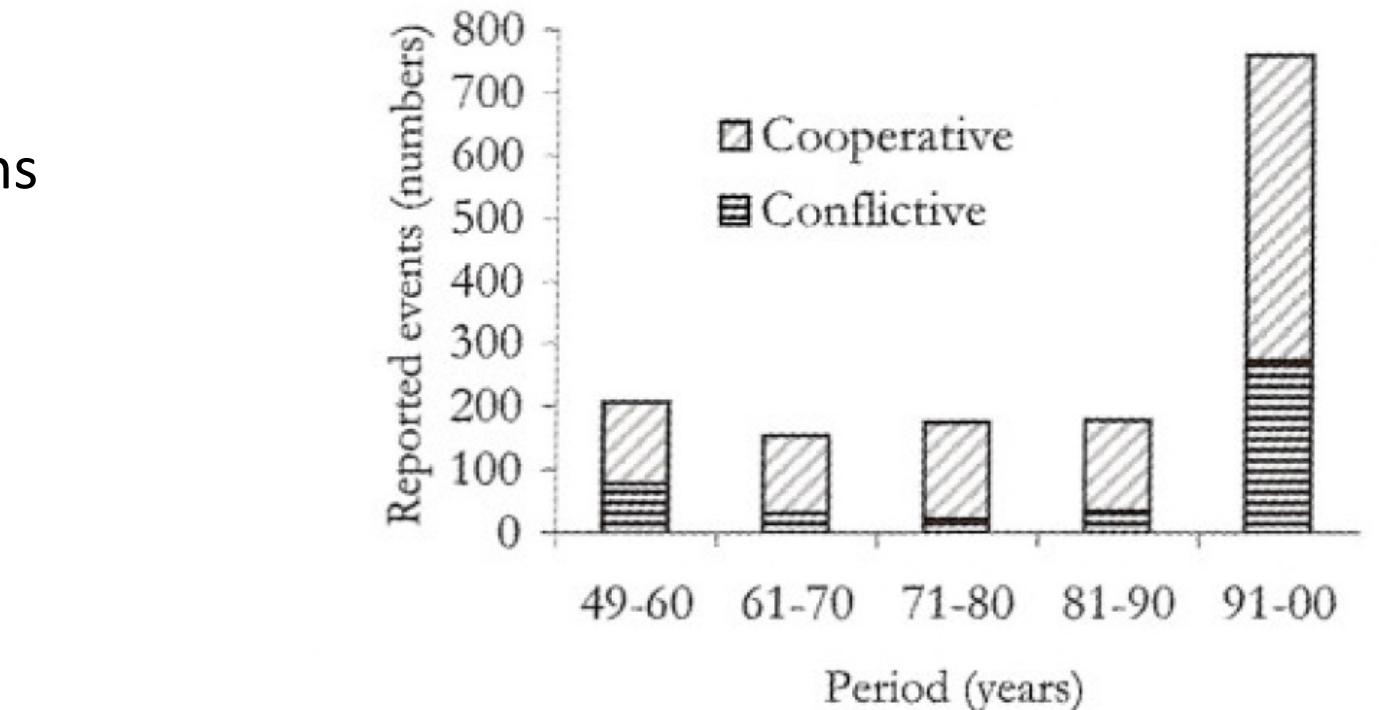


- Conflicts is usually measured as the number of unsolved water availability problems between riparian states



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



Conflictive and cooperative water events over the last 50 years.

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

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

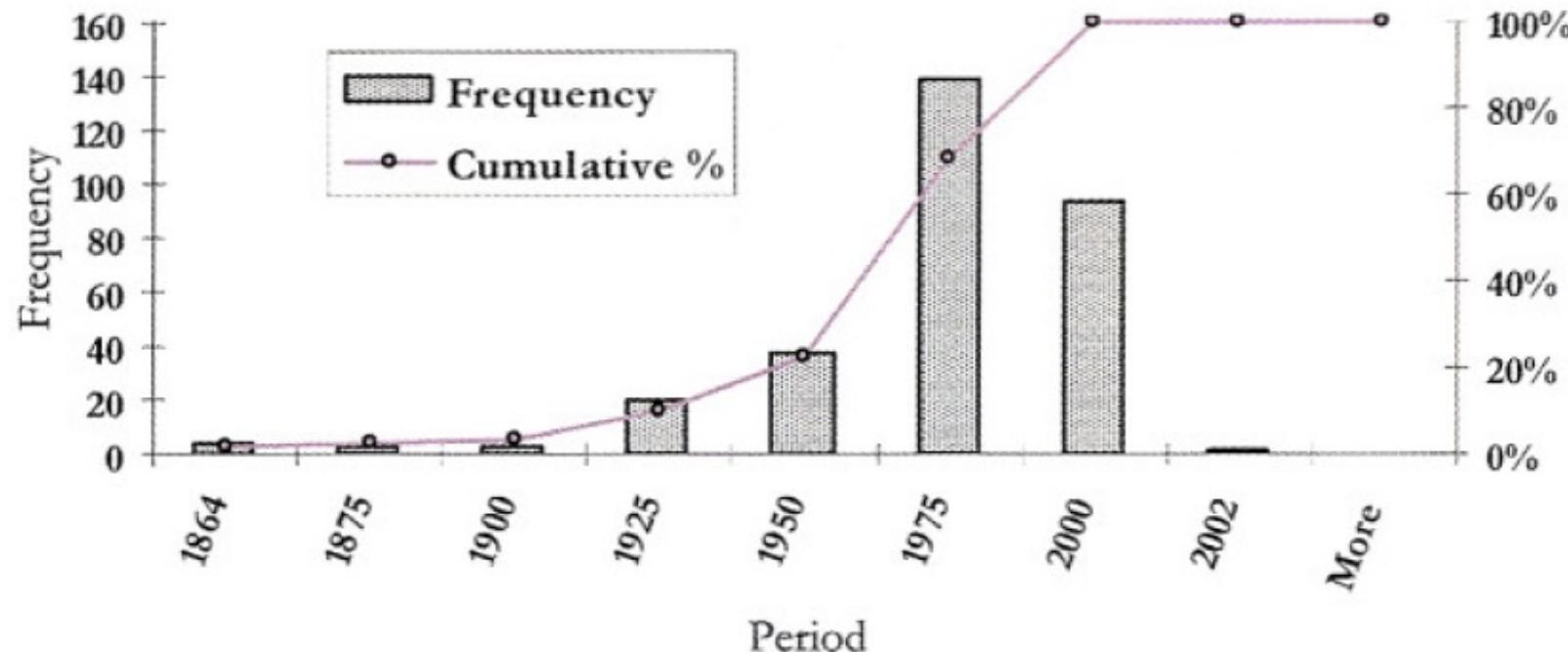


Fig. 1.7: Distribution of bilateral **treaties** during 1864–2002.

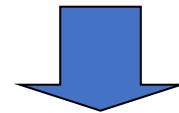
Please, visit <https://transboundarywaters.ceoas.oregonstate.edu/international-freshwater-treaties-database>

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_DocID	TFDDID	Unified Primary 2016 Treaty ID	Primary2010_Treaty_DocID	PrimaryT FDDID	DocumentName	DateSigned	Signatori es	Meets Inclusion Criteria	Governance Level	Binding Nature	Doc Lineage	DocType	Format	Source	Notes	LocationSigned	Region_Continent	PRIMARY_COUNTRY_SUBREGION	Treaty Basin(s)	TFDD Basin(s)	NumberParties	AdditionalComments	MinorAgreement	Reference to Precedence	Agreement Purpose	GeoScope	Issue Area	RB
1																																			
12	11_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	3	3	392	3	3	392	3	Convention between the de 8/31/1857	Austria, Bad	1	1	1	1	1	4	French, elect	UNIS 391	States agree N.A.	Europe	Western Eur	Lake Constan	Rhine	2	N	1, 2, 3	5	Infrastructure, Funding				
66	66_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	16	16		16		392	3	Convention Between Swi 5/18/1887	Switzerland	1	1	1	2		9	French, elec	https://eaex	Switzerland Lucerne, S	Europe	Western Eu	Rhine, Lake Rhine		2	Y	2, 1, 2	5	Water Quality, Fisher				
79	79_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	21	21		21		392	3	Agreement concerning the I 5/18/1890	Germany, Switzerland						9	Missing		Listed in EEA N.A.	Europe	Western Eur N.A.	Rhine	1	N.A.	0	0	0	0 N.A.				
235	235_RHON_CHE	RHON	Rhone CHE	Switzerland	51	52	242	51	52	242	242	Convention between France 04.10.13	Switzerland	1	1	1	1	1	4	French, electronic		Bern, Switz	Europe	Western Eur	Rhine	1	N	1, 2, 3	5	Infrastructure, Hydrop					
315	315_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	72	73	241	24	24	237	237	Treaty between the Swiss 02.11.25	Switzerland	1	1	1	1	1	7	French, electronic		Vienna, Aus	Europe	Europe	Rhine, Lake Rhine	1	N	1, 1, 3	5	Water Quantity, Infras					
359	360_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	88	90		88	90	237	237	Convention between Germa 12.04.05	Germany, Switzerland						9	Missing		Listed in EEA N.A.	Europe	Western Eur N.A.	Rhine	1	N.A.	0	0	0	0 N.A.				
374	375_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	92		92			375	Protocol determining the 18.12.29	Germany, France, Switzerland						7	Electronic	United Nat	They are cai Geneva, Sw	Europe	Western Eu	Rhine, betw Rhine-Meu	2	N	2, 1, 2, 3	5	Infrastructure						
375	376_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	93	96		0		376	Protocol to the Protocol det 03.01.30	Germany, France, Switzerland						9	Missing		Listed in EEA N.A.	Europe	Western Eur N.A.	Rhine	2	N.A.	0	0	0	0 N.A.					
382	383_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	96	99	235	582	642	382	Convention for the settle 27.08.26	France, Swit	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	384	Convention between Switz 19.11.30	France, Swit	1	1	1	1	1	4	French, electronic		Bern, Switz	Europe	Doubs, Rh	Rhine	1	N	1, 1, 2	5	Infrastructure, Hydrop						
512	513_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	140	143	398	140	143	398	398	Accord between Switzerl 18.06.49	Switzerland	1	1	1	1	1	4	French, electronic		Rome, Ital	Europe	Rhine-Meu	Rhine-Meu	1	N	1, 1, 2	5	Infrastructure, Hydrop					
546	547_POKX_CHE	POXX	Po CHE	Switzerland	153	158	213	153	158	213	213	Convention between the 05.04.51	Switzerland	1	1	1	1	1	4	French, electronic		Chiasso, Ital	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	237	237	Treaty between the Swiss 10.04.54	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_POKX_CHE	POXX	Po CHE	Switzerland	188	194	210	188	194	210	210	Convention between Swi 17.09.55	Switzerland	1	1	1	1	1	4	French, electronic		Lugano, Swi	Europe	Po	Po	1	N	1	2	5	Flood Management, Fu				
694	695_POKX_CHE	POXX	Po CHE	Switzerland	204	211	395	204	211	395	395	Convention between the 27.05.57	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	238	Convention between Swi 03.12.59	Switzerland	1	1	1	1	1	4	French		Paris, Franc	Europe	Western Eu	Boiron, Rh	1	N	1	3	5	Territorial and Border I				
769	770_RHON_CHE	RHON	Rhone CHE	Switzerland	225	232	239	225	232	239	239	Convention between Swi 03.12.59	Switzerland	1	1	1	1	1	4	Partial text - Annex is		Paris, Franc	Europe	Western Eu	Rhine	1	N	1	3	5	Territorial and Border I				
819	820_RHON_CHE	RHON	Rhone CHE	Switzerland	245	254	295	245	254	295	295	Convention concerning prot 16.11.62	France, Switzerland						4	Electronic	922 UNTS 3; 1974 UNTS 5	N.A.	Europe	Western Eur	Lake Geneva	1	N	1	2	5	Water Quality				
825	826_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	248	257	294	248	257	294	294	Agreement on the Internat 29.04.63	France, Germany, Federal Republic of, Luxembourg, Netherlands, S						4	Electronic	994 UNTS 17	N.A.	Europe	Western Eur	Rhine	2	N	1	2	5	Water Quality				
974	975_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	278	290	134	278	290	134	134	Agreement between West 30.04.66	Switzerland	1	1	1	1	1	4	French		Berne, Europe	Western Eur	Rhine	Rhine	2	N	2, 5	4	5	Water Quantity				
985	986_RHON_CHE	RHON	Rhone CHE	Switzerland	284	298	236	284	298	236	236	Convention between the 23.08.63	Switzerland	1	1	1	1	1	4	French, electronic		Sion, Switz	Europe	Western Eu	l'Eau Noire, Rhone	1	N	3, 1, 2	5	Hydropower, Infrastru					
1094	1095_POKX_CHE	POXX	Po CHE	Switzerland	309	327	219	309	327	219	219	Exchange of letters on Ju 15.06.70	Switzerland	1	1	1	1	1	4	French, electronic		Western Eu	Po	Po	1	N	1, 1, 3	5	Flood Management, Fu						
1151	1152_RHON_CHE	RHON	Rhone CHE	Switzerland	319		319			21.10.71	France, Switzerland						7	Electronic	United Nat	Treaty purs	N.A.	Europe	Western Eu	Lake Geneva	1	In the form	2	3	5	Water Quality					
1165	1166_DANU_CHE	DANU	Danube CHE	Switzerland	325	346	259	325	346	259	259	Convention concerning the 20.04.72	Italy, Switzerl						4	Electronic	957 UNTS 279; www.fao	Rome	Europe	Western Eur	Lake Maggi	1	Concerns pro N	1	2	3	Water Quality				
1167	1168_POKX_CHE	POXX	Po CHE	Switzerland	325	346	259	325	346	259	259	Convention concerning the 20.04.72	Italy, Switzerl						4	Electronic	957 UNTS 279; www.fao	Rome	Europe	Western Eur	Lake Maggi	1	Concerns pro N	1	2	3	Water Quality				
1169	1170_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	325	346	259	325	346	259	259	Convention concerning the 20.04.72	Italy, Switzerl						4	Electronic	957 UNTS 279; www.fao	Rome	Europe	Western Eur	Lake Maggi	1	Concerns pro N	1	2	3	Water Quality				
1175	1176_POKX_CHE	POXX	Po CHE	Switzerland	327	348	388	327	348	388	23.06.72	Switzerland	1	1	1	1	1	4	French, electronic		Bern, Switz	Europe	Po	Po	1	N	2, 2, 3	5	Infrastructure, Fundin						
1270	1271_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	360	385	300	248	257	294	294	Convention on the protecti 03.12.76	France, Germany, Federal Republic of, Luxembourg, Netherlands, S						7	Electronic	1404 UNTS 90; 16 ILM 242	Bonn	Europe	Western Eur	Rhine-Meuse	2	N	2	1	1	5	Water Quality			
1275	1276_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	361	386	340	248	257	294	294	Convention on the protecti 03.12.76	European Economic Community, France, Germany, Federal Republi						7	Electronic	1124 UNTS 405; www.fao	N.A.	Europe	Western Eur	Rhine	2	N	2	2	4	Water Quality				
1284	1285_RHON_CHE	RHON	Rhone CHE	Switzerland	362	388	293	362	388	293	293	Agreement concerning the 05.05.77	France, Switzerland						4	Electronic	1080 UNTS 159	N.A.	Europe	Western Eur	Lake Geneva	1	Establishes p N	1	3	5	Water Quality				
1357	1360_RHON_CHE	RHON	Rhone CHE	Switzerland	387	417	191	245	254	295	295	Decree number 81-1130	20.11.80	France, Swi	1	1	1	1	1	7	French, electronic		Bern, Switz	Europe	Western Eur	Leman Rhone	1	N	1	1	1	5	Environment, Funding		
1444	1449_UNKN_CHE	UNKN	Unknown CHE	Switzerland	411	450	411	450	411	450	23.02.87	France, Switzerland						3	French, electronic		Rome, Italy	Europe	Western Eur	Lake Maggi	1	N	1, 2, 3	5	Fisheries, Environment						
1452	1457_RHON_CHE	RHON	Rhone CHE	Switzerland	415	454	415	454	415	454	23.02.87	France, Switzerland						2	French	http://faolex	N.A.	Europe	Western Eur	Lake Geneva	1	N.A.	0	0	0	0 N.A.					
1469	1474_RHON_CHE	RHON	Rhone CHE	Switzerland	418	457	355	418	457	355	355	Convention introducing	10.06.87	Le canton	1	1	1	1	1	2	French, electronic		Bern, Switz	Europe	Western Eur	Rhine	1	N	1, 1, 2	5	Infrastructure, Environ				
1528	1533_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	440	481	337	440	481	337	337	Agreement between the go	17.05.90	Land Baden Wurttemberg, Switzerland						9	Missing		N.A.	Europe	Western Eur	Rhine	1	No commis	0	0	0	0 N.A.			
1564	1569_RHON_CHE	RHON	Rhone CHE	Switzerland	450		496	335	360	385	300	Implementing regulation	29.07.91	French Republic, Swiss Federal Council						4	Electronic	Most of the	Paris, Franc	Europe	Western Eur	Doubs	1	Y	2, 3	1	5	Fisheries, Environment			
1601	1606_RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	452	496	335	360	385	300	300	Additional protocol to the o	25.09.91	France, Germany, Federal Republic of, Luxembourg, Netherlands, S						7	Electronic	1994 UNTS 372	Bonn	Europe	Western Eur	Rhine	2	N	2	1	1	5	Water Quality		

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

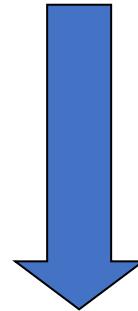


Strategies begin to appear in order to maximize benefits of the involved riparian states

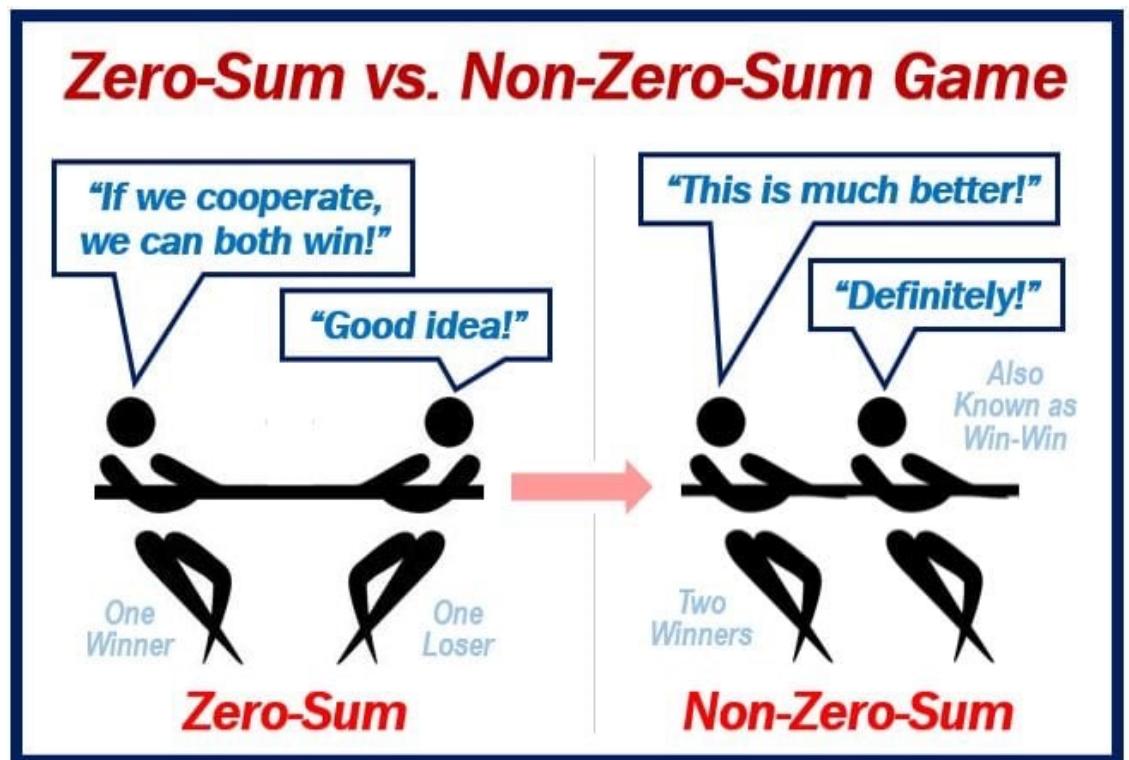


Objective functions are therefore discontinuous and classic optimization tools are not adequate!

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

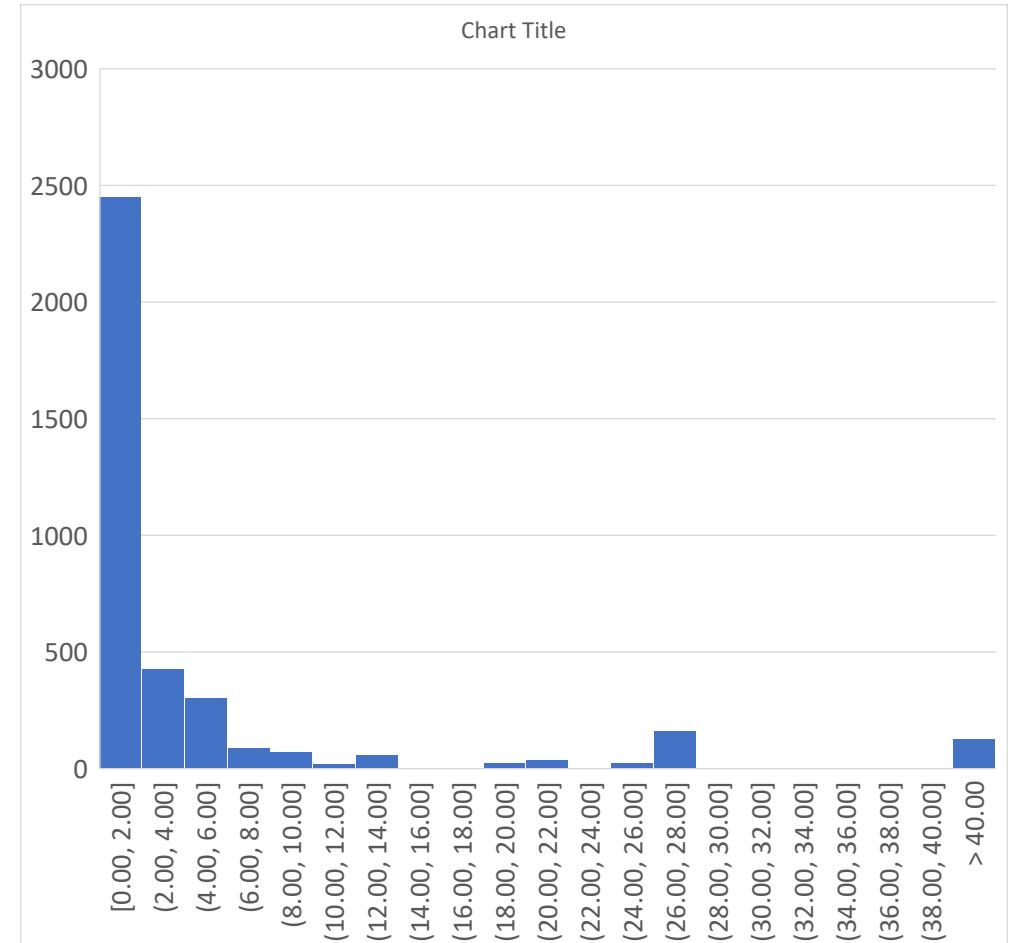


GAME THEORY
(Zero sum vs Non-zero sum games)



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.ceolas.oregonstate.edu/international-freshwater-treaties-database>

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1																		
12	11	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	3	3	392	3	3	3	392 Convention between the delegates of the riparian states of Lake Constance: Bade, Bavaria, Austria, Switzerland and Wurtemberg, concerning the regulation of the Rhine 8/31/1857	Austria, Bade, Bavaria, Switzerland, Wurtemberg		1	1		
66	66	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	16	16		16			Convention Between Switzerland, The Grand Duchy of Baden, And Alsace-Lorraine, Establishing Uniform Provisions On Fishing In The Rhine 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	Germany, Switzerland					
235	235	RHON_CHE	RHON	Rhone CHE	Switzerland	51	52	242	51	52	242	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 point 04.10.13	Switzerland, France		1	1		
315	315	RHIN_CHE	RHIN	Rhine-Meuse 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'Il to Lake Constance	Switzerland, Austria	02.11.25				
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	Germany, Switzerland					
374	375	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	92			92			Protocol determining the methods of technical and administrative co-operation between Germany, France and Switzerland in the work force	Germany, France, Switzerland	18.12.29				
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 force	Germany, France, Switzerland	03.01.30				
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	France, Switzerland	27.08.26				
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 Chatelot waterfall	France, Switzerland	19.11.30				
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	Switzerland, Italy	18.06.49				
546	547	POX_CHE	POXX	Po CHE	Switzerland	153	158	213	153	158	213	213 Convention between the Swiss Confederation and the Italian Republic concerning the correction of the Roggia Molinara canal (commune of Brissago)	Switzerland, Italy	05.04.51				
584	585	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	169	175	220	24	24	237	237 Treaty between the Swiss Confederation and the Republic of Austria for the regularization of the Rhine from the opening of the Ile of Lake Lugano	Switzerland, Austria	10.04.54				
644	645	POX_CHE	POXX	Po CHE	Switzerland	188	194	210	188	194	210	210 Convention between Switzerland and Italy about the regularization of Lake Lugano	Switzerland, Italy	17.09.55				
694	695	POX_CHE	POXX	Po CHE	Switzerland	204	211	395	204	211	395	395 Convention between the Swiss Confederation and the Republic of Italy about the utilisation of the hydraulic force of the Spöl	Switzerland, Italy	27.05.57				
767	768	RHON_CHE	RHON	Rhone CHE	Switzerland	224	231	238	224	231	238	238 Convention between Switzerland and France concerning the correction of the Boiron stream	Switzerland, France	03.12.59				
769	770	RHON_CHE	RHON	Rhone CHE	Switzerland	225	232	239	225	232	239	239 Convention between Switzerland and France about a correction to the Hermance	Switzerland, France	03.12.59				
819	820	RHON_CHE	RHON	Rhone CHE	Switzerland	245	254	295	245	254	295	295 Convention concerning protection of the waters of Lake Geneva against pollution	Switzerland, France	16.11.62				
825	826	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	248	257	294	248	257	294	294 Agreement on the International Commission for the protection of the Rhine against pollution	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation	29.04.63				
974	975	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	278	290	134	278	290	134	134 Agreement between West Germany, Austria, and Switzerland relating to the withdrawal of water from Lake Constance	Switzerland, German Fed. Rep., Austria	30.04.66				
985	986	RHON_CHE	RHON	Rhone CHE	Switzerland	284	298	236	284	298	236	Convention between the Swiss Confederation and the Republic of France about the hydroelectric layout of the Emosson	Switzerland, France	23.08.63				
1094	1095	POX_CHE	POXX	Po CHE	Switzerland	309	327	219	309	327	327	Exchange of letters on June 15, 1970 between Switzerland and Italy concerning the organization of the water flow of the Breggia on the Ile of Brissago	Switzerland, Italy	15.06.70				
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 1970	France, Switzerland	21.10.71				
1165	1166	DANU_CHE	DANU	Danube CHE	Switzerland	325	346	259	325	346	259	259 Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	Italy, Switzerland	20.04.72				
1167	1168	POX_CHE	POXX	Po CHE	Switzerland	325	346	259	325	346	259	259 Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	Italy, Switzerland	20.04.72				
1169	1170	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	325	346	259	325	346	259	259 Convention concerning the protection of Italo-Swiss waters against pollution, signed at Rome	Italy, Switzerland	20.04.72				
1175	1176	POX_CHE	POXX	Po CHE	Switzerland	327	348	388	327	348	348	24 Convention between Switzerland and Italy about the layout of the hydraulic flow of the Breggia at the Italian-Swiss border	Switzerland, Italy	23.06.72				
1270	1271	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	360	385	300	248	257	294	294 Convention on the protection of the Rhine against pollution by chlorides (with annexes and exchanges of letters dated 1983), concluded at Bonn	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation	03.12.76				
1275	1276	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	361	386	340	248	257	294	294 Convention on the protection of the Rhine against chemical pollution	European Economic Community, France, Germany, Federal Republic of, Luxembourg, Netherlands, Switzerland	03.12.76				
1284	1285	RHON_CHE	RHON	Rhone CHE	Switzerland	362	388	293	362	388	388	293 Agreement concerning the activities of agencies for the control of accidental water pollution by hydrocarbons or other substances capable of contaminating water	France, Switzerland	05.05.77				
1357	1360	RHON_CHE	RHON	Rhone CHE	Switzerland	387	417	191	245	254	254	295 Decree number 81-1130 from December 15, 1981, about an accord between the Government of the Republic of France and the Swiss Federal Council concerning the protection of the Rhine against pollution	France, Switzerland	20.11.80				
1444	1449	UNKN_CHE	UNKN	Unknown CHE	Switzerland	411	450	411	450	411	450	295 Convention between the Swiss Confederation and the Republic of Italy about fisheries within Italian-Swiss waters	Italy, Switzerland	19.03.86				
1452	1457	RHON_CHE	RHON	Rhone CHE	Switzerland	415	454	415	454	415	454	295 Convention instituting the Council of Lake Geneva	France, Switzerland	19.02.87				
1469	1474	RHON_CHE	RHON	Rhone CHE	Switzerland	418	457	355	418	457	355	295 Convention introducing the Council of Leman, Lausanne, on February 19, 1987, and the exchange of letters from June 10, 1987	Le canton de Vaud, Le canton de Valais, Le canton de Genève, Le department de l'ain, Le department de la haute-savoie	10.06.87				
1528	1533	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	440	481	337	440	481	337	295 Agreement between the government of the Land Baden-Württemberg and the Swiss Federal Council concerning the joint construction and operation of a dam on the Rhine	Land Baden-Württemberg, Switzerland	17.05.90				
1564	1569	RHON_CHE	RHON	Rhone CHE	Switzerland	450						295 Implementing regulations of the agreement between the government of the French Republic and the Swiss Federal Council concerning the protection of the Rhine against pollution from chlorides	French Republic, Swiss Federal Council	29.07.91				
1601	1606	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	452	496	335	360	385	300	300 Additional protocol to the convention on the protection of the Rhine against pollution from chlorides	France, Germany, Federal Republic of, Luxembourg, Netherlands, Swiss Confederation	25.09.91				
1680	1685	GRNL_CHE	GNRL	General CHE	Switzerland	461						295 Convention on the protection and use of transboundary watercourses and international lakes	Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Cameroon, Chad, Croatia, Czech Republic, D	17.03.92				
1878	1883	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	516	567	256	516	567	256	295 Convention relative to the collection, deposit, and the reception of trash occurring during navigation of the Rhine and the interior	Belgium, Germany, Luxembourg, Netherlands, Switzerland, France	09.09.96				
1899	1904	RHON_CHE	RHON	Rhone CHE	Switzerland	526	579	526	579	526	579	295 Règlement sur la manœuvre de l'ouvrage de régularisation du niveau du lac Léman à Genève	Switzerland	17.09.97				
1921	1926	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	535	589	193	248	257	257	294 Convention on the protection of the Rhine	France, Luxembourg, German Fed. Rep., Switzerland, Netherlands, European Union	22.01.98				
1953	1958	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	548	602		248	257	257	294 Convention on the Protection of the Rhine	Germany, France, Switzerland	12.04.99				
2132	2137	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	582		642	582	582	642	294 Agreement concerning the scheme for the Kembs lateral canal, with procs-verbal	France, Switzerland	10.05.22				
2188	2193	RHON_CHE	RHON	Rhone CHE	Switzerland	595	1004		245	254	191	191 Exchange of notes constituting an amendment concerning the agreement between the government of the French Republic and the Swiss Federal Council	France, Switzerland	19.09.95				
2292	2297	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	630	1077		0			295 Revised convention relating to the navigation of the Rhine	France, Grand Duchy of Baden, Bavaria, Grand Duchy of Hessen, Netherlands, Prussia	10/17/1868				
2296	2301	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	631	1078		0			295 Convention regulating the relations with regard to certain clauses of the legal regime of the future Kembs derivation, with additional protocol	Swiss Federal Council, French Republic	27.08.26				
2495	2500	GRND_CHE	GRND	Groundwater CHE	Switzerland	677						295 Convention on the protection, utilization, recharge, and monitoring of the Franco-Swiss genevois Aquifer	France: Communities of Annemasseenne and Genevois rural district and rural district of Viry; Switzerland: Republic and Canton of Geneva	18.12.07				
2596	2601	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	701						295 Convention between Germany and Switzerland regarding the regulation of the Rhine between Strasbourg-Kehl and Istein. Signed at Berne, March 28, 1972.	Swiss Confederation, German Reich	28.03.29				
2687	2690	GRND_CHE	GRND	Groundwater CHE	Switzerland	727						295 Charter on Groundwater Management	UNECE member states	00/00/1989				
2772	2775	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	743						295 Protocol determining the methods of technical and administrative cooperation between Germany, France and Switzerland in the work force	Germany, France, and Switzerland	18.12.29				
2962	2965	DANU_CHE	DANU	Danube CHE	Switzerland	775						295 Treaty of Peace with Germany (Treaty of Versailles)	United States, United Kingdom, Dominion of Canada, Commonwealth of Australia, Union of South Africa, Commonwealth of New Zealand, India, France, Italy, Spain	28.06.19				
2984	2987	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	775						295 Treaty of Peace with Germany (Treaty of Versailles)	United States, United Kingdom, Dominion of Canada, Commonwealth of Australia, Union of South Africa, Commonwealth of New Zealand, India, France, Italy, Spain	28.06.19				
3408	3411	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	849						295 Convention signed at Strasbourg on November 20 1963, amending the revised Convention for Rhine Navigation signed at Mannheim on April 29, 1963	United Kingdom, Dominion of Canada, Commonwealth of Australia, Union of South Africa, Commonwealth of New Zealand, India, France, Italy, Spain	20.11.63				
3422	3425	GRND_CHE	GRND	Groundwater CHE	Switzerland	852						295 Agreement on the protection, utilization, and recharge of the Franco-Swiss Genevois Aquifer	Federal Republic of Germany, Kingdom of Belgium, French Republic, The United Kingdom of Great Britain and Northern Ireland, Kingdom of the Netherlands	09.06.77				
3457	3460	RHIN_CHE	RHIN	Rhine-Meuse CHE	Switzerland	858						295 Supplementary agreement to the agreement concluded in Bern on April 29, 1963 about the International Commission for the Protection of the Rhine	Federal Republic of Germany, French Republic, Grand Duchy of Luxembourg, Kingdom of the Netherlands, Swiss Confederation, European Economic Comm	03.12.76				

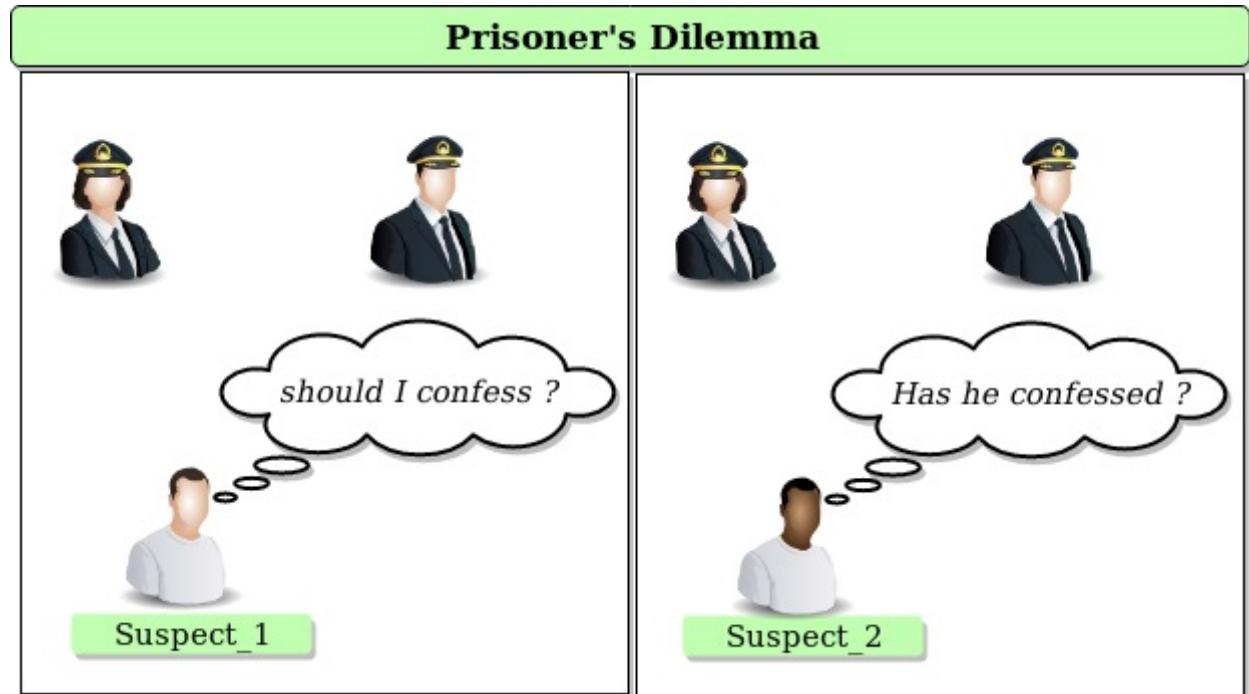
The foundation of strategic analysis

- 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

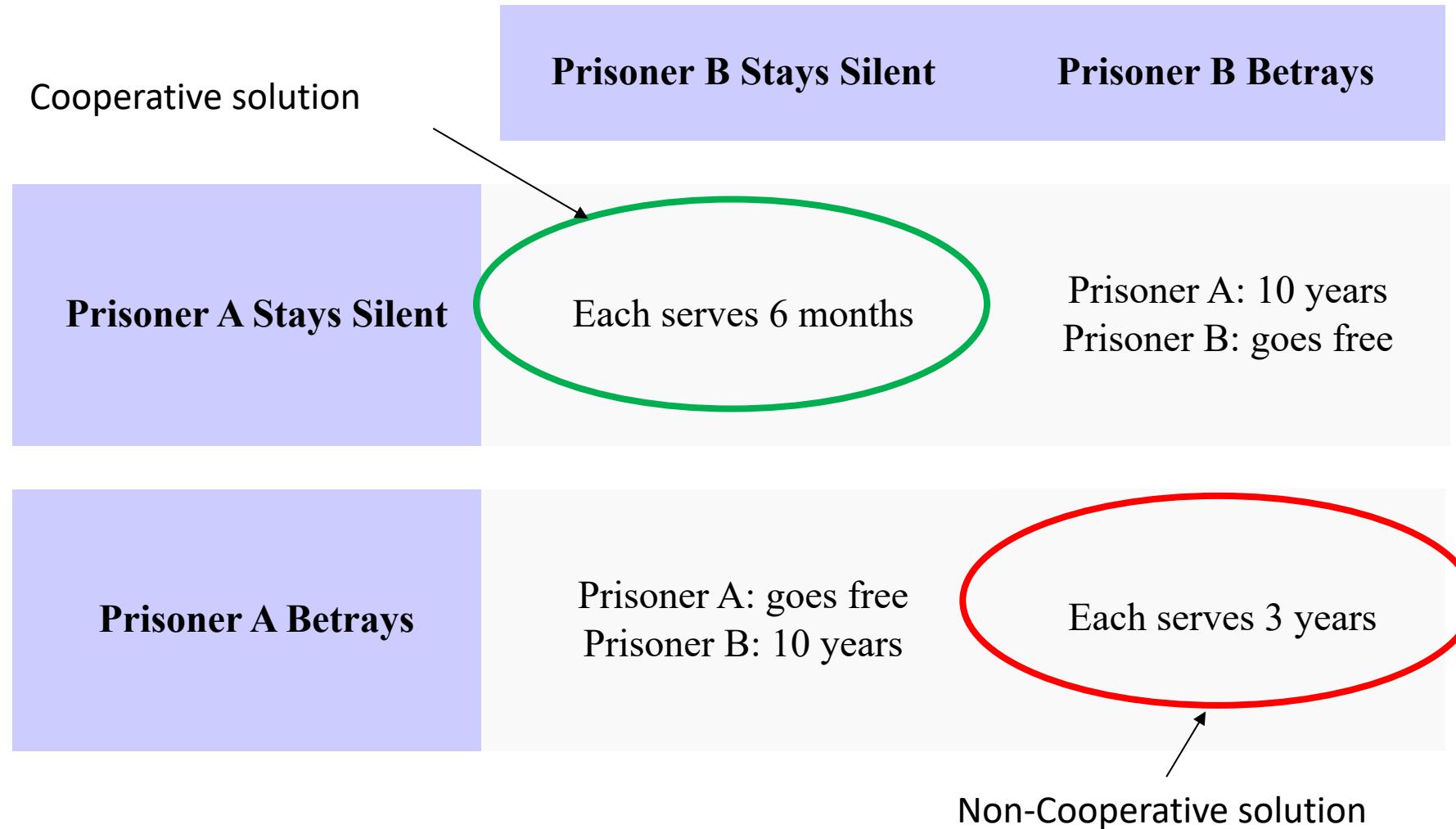


Prisoner's dilemma

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



Example PD payoff matrix

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

Win-lose terminology

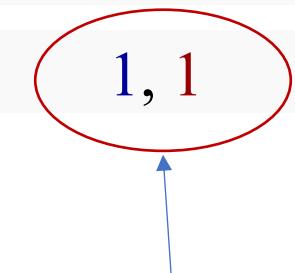
		Cooperate	Defect
		Cooperate	Defect
Cooperate	Cooperate	win-win	lose much-win much
	Defect	win much-lose much	lose-lose

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

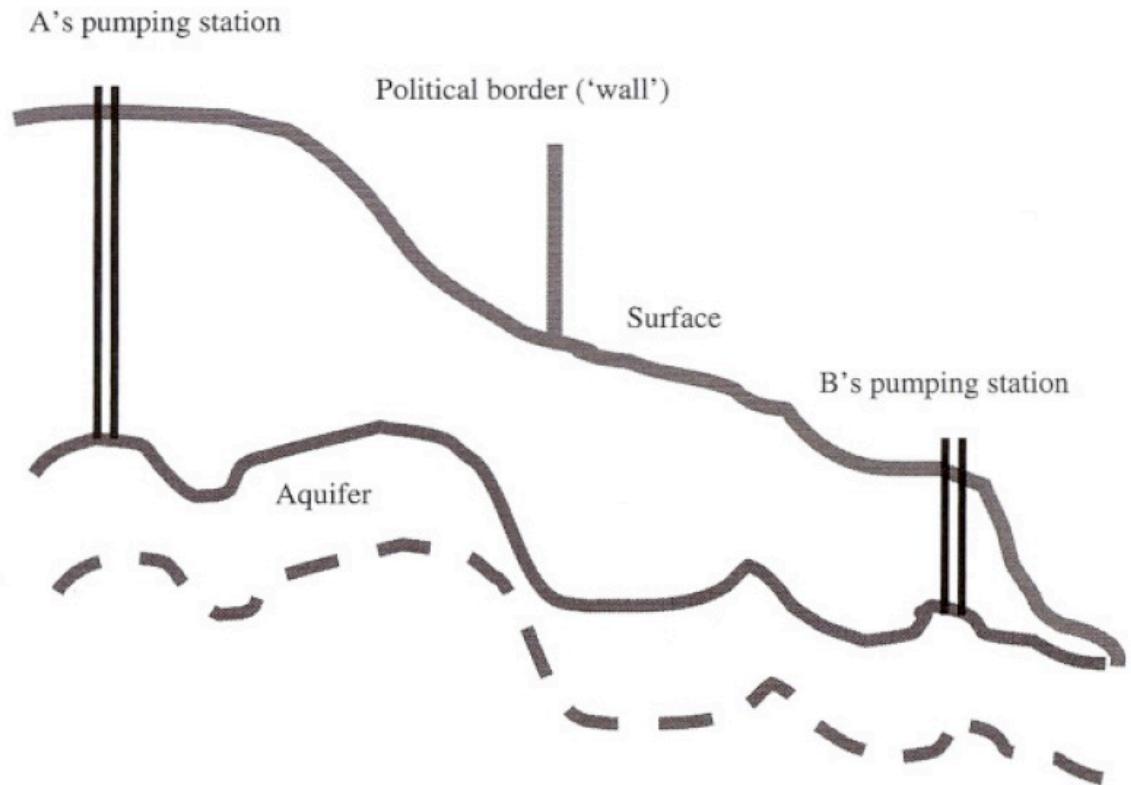


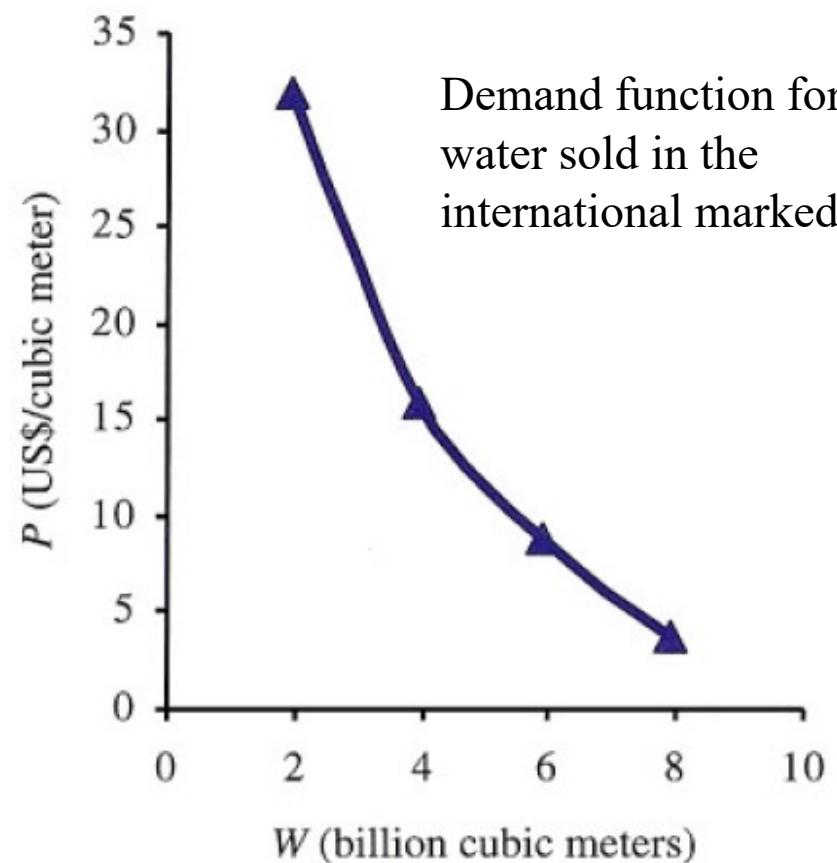
Nash equilibrium,
or lose-lose
situation

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 is 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 $16*(2)-2*(0.6)=30.8$

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

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

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

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

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

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

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

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

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

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

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)	2	30.8 31.6
	4	33.6 17.6	13.6 15.2

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 in dump)
- 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