Proposed model for sharing contested transboundary water resources

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Abstract

The sharing of trans-boundary water resources is increasingly becoming one of the most contentious issues confronting sustainable utilization of water resources. While allocation between upstream and downstream users continues to be constrained by lack of adequate data and uncertainties on future availability because of global climate change, a related problem is lack of mutually agreeable water sharing mechanisms. This constraint appears to be persevering because of failures by the scientific community to formulate water sharing strategies that harmonise the varied interests of numerous stakeholders. Because lack of agreeable sharing arrangements tends to encourage self-centred resource use practices that undermine sustainable utilisation, research needs to formulate work-around strategies that enhance sustainable use by promoting responsible stewardship. In recognition of the general lack of agreeable sharing mechanisms, the objective of this contribution is to offer an empirically based model that is potentially capable of providing an objective basis for distributing contested trans-boundary water resources. With its underpinnings in classical game theory, the model presented in this paper uses data on absolute hydrography and water demand by different sectors to determine the distribution of this resource in Southern Africa's Okavango drainage basin where sustainable use of the Okavango River's water by Angola, Namibia and Botswana is threatened by disagreement over quantities each of these countries can abstract. Results of our analysis suggest that the model offers a mechanism that is worth exploring as a basis for allocating water when collective action is undermined by lack of mutually agreeable criteria.

Keywords: Okavango basin, hydroconflict, game theory.

1. Introduction

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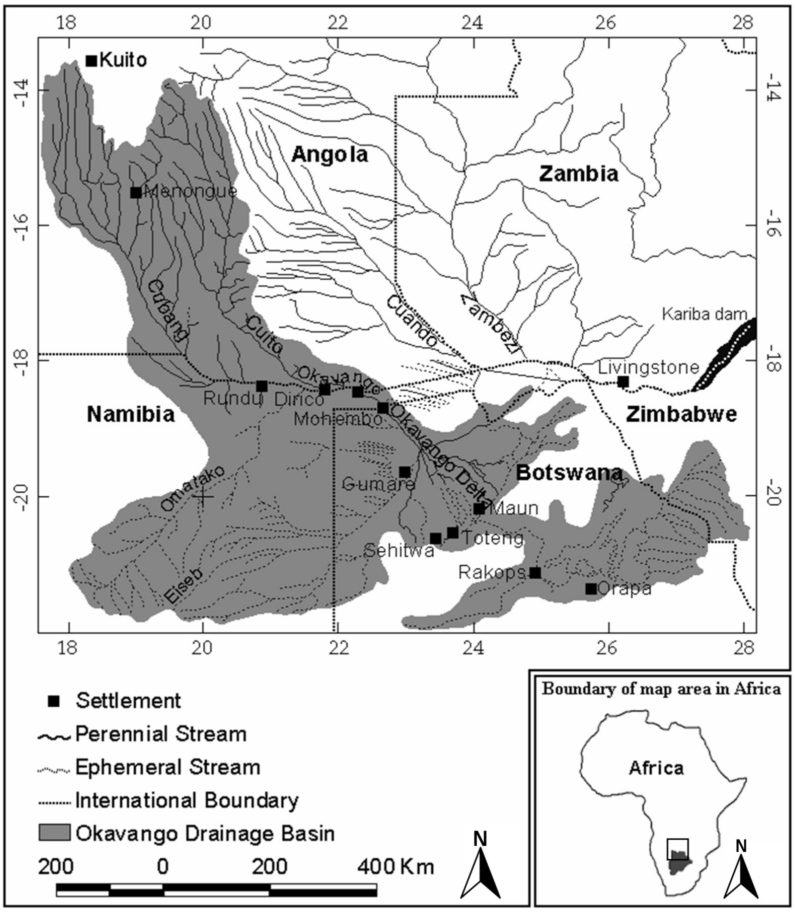
Equitable allocation of transboundary water resources is problematic because of spatial disparities in natural endowment, imbalances in levels of demand by co-riparian states and lack of agreeable sharing arrangements. Regional variations in climate often aggravate the situation by imposing dependence of water deficit areas on inflows from outside their boundaries. One positive outcome of this phenomenon has been cooperation between water-deficit and water-rich countries. Though water's unifying role is apparent, instances in which it has been a major cause of conflict are also evident. Conflict is often incited by unequal access and similar claims to limited supplies because of differences in natural endowment, demand patterns and lack of agreeable sharing arrangements. The latter has been a major source of persistent tensions that undermine inter-state collaboration by encouraging the adoption of unilateral development initiatives. Tensions can escalate into conflict when upstream countries deny their downstream counterparts adequate access by disproportionately exploiting resources within their boundaries. Though asymmetries in access may be the direct result of inconsiderate exploitation, non natural factors such as drought occasionally aggravate the situation by effectively reducing sharable quantities. For Southern Africa, this phenomenon has prompted the consideration of ambitious projects such as the transfer of water from the Congo River southward to augment supplies in the Okavango basin via the Okavango system. The wisdom informing this imaginative initiative is that inter-basin transfers can provide effective stop-gap interventions that are potentially capable of preempting impending conflicts by providing adequate supplies to water-deficit areas without compelling water-rich partners to forfeit their sovereign rights to fully exploit resources within their political boundaries. Though the utility of this intervention is difficult to ascertain, a pursuable strategy under the present situation appears to revolve around the formulation of mechanisms that can enhance judicious distribution of the basin's accessible resources. We attempt to provide a mechanism for such distribution in this paper by tapping on the constructs of classical Game Theory to provide objectively determined criteria for rationalizing the distribution of the Okavango basin's contested transboundary water resources.

2. Geographical and hydrological context

The Okavango drainage basin is from a broad perspective a water poor region that straddles four countries; Angola, Namibia, Botswana and Zimbabwe. It has a population of about 580 000 people (Nicol, 2002) and covers an estimated 530 000km^2 (Heyns, 2003) politically subdivided into four sub-basins the largest of which is situated in Botswana. Botswana and Namibia's portions are the most arid, depending to a large extend on external flows from Angola. Zimbabwe's portion is negligible both in terms of spatial coverage and its contribution to surface runoff. In terms of surface drainage, the entire basin can be divided into humid and arid sub-catchments above and below latitude 18°S in Angola and, Namibia and Botswana respectively (Figure 1).

Figure 1 Extent and Location of the Okavango drainage basin



Mean annual rainfall decreases from north to south; 1 300mm in Angola's Cubango-Cuito catchment and 400mm around Orapa in Botswana. Annual runoff averages 300mm in Angola declining to ~80mm at Dirico (IUCN, 1992). Because of these hydrological distinctions, 95% of the basin's estimated 10000 million cubic meters of annual runoff is mobilized in Angola (Heyns, 2003). The major shared river is the Okavango which sustains the Okavango Delta by contributing 76.5% of all inflow into the system with the remaining 23.5% coming from direct rainfall (McCarthy and Bloem, 1998). Most of the basin below 18°S experiences a semi-arid climate characterised by periodic droughts, erratic rainfall and high rates of evaporation averaging 2000mm/annum (Eastend Investments, 1996). Table 1 shows the distribution of sub-basins by basin-state and the proportion of each as a percentage of the main basin's total area, mean annual rainfall and corresponding runoff-yields as percentages of total inflows into the Okavango River. The same table also shows population distribution and, current and projected levels of water offtake as percentages of the three countries' combined offtake from the same river.

Table 1 Distribution of sub-basins; mean annual rainfall, runoff contribution, population distribution and water consumption by basin-state in the Okavango drainage basin

Basin State	Sub-basin area		Mean annual rainfall (mm)	Runoff contribution (percentage)	Population as percentage of total	Offtake from Okavango as percentage of mean flow/annum	
	Km^2 (000s)	Percentage of total					
Angola	200	27.6	1200	94.5	76	60[a]	40[b]
Namibia	340	22.8	400	2.9	13	22[a]	42[b]
Botswana	165	46.9	400	2.6	11	18[a]	18[b]
Total	**725**	**100**	**—**	**100**	**100**	**100**	**100**

[a]Current and [b]projected consumption by year 2020 as percentages of combined offtake.

Sources: Ashton and Neal, 2003; Savenije and van der Zaag, 1997.

3. Water demand scenarios

Table 2 summarises water demands in the basin by Angola, Namibia and Botswana.

Table 2 Water demands in the Okavango basin by Angola, Namibia and Botswana

Water-use sector		Quantities in million cubic meters per year			
		Angola	**Botswana**	**Namibia**	**Total**
Stock watering		0.250	0.267	0.145	0.662
Tourism facilities		0.000	0.418	0.100	0.518
Industrial activities		0.000	0.025	0.060	0.085
Domestic use: urban		7.445	0.699	0.813	8.957
Subsistence use: rural		5.646	1.484	1.266	8.396
Agricultural activities		0.500	1.220	2.830	4.550
Total:	Quantity per annum	**13.841**	**4.113**	**5.214**	**23.168**
	As percentage of available supplies	**59.7**	**17.8**	**22.5**	**100.0**

Source: Ashton, 2003.

The major water-utilization issues in this area relate to increasing scarcity amidst escalating demands because of a fast growing population that has been projected to increase from 580 000 in 2000 to 1.686 million by 2020 (Swatuk, 2002). While demand is escalating, sustainability is being threatened by declining rainfall (Hamandawana et al., 2008), management approaches that are biased in favour of increasing exploitation (Hamandawana et al., 2007) and anticipated development of Angola’s irrigation potentials. In Namibia, high population densities along the Okavango River (40-100/km^2), rapid population growth (7.5%/annum) and a projected increase in population from 179 400 in 2000 to 216 000 by 2020 imply increased water use at levels that might be difficult to sustain (el Obeid and Mendelsohn, 2000). Though Namibia’s use of water from the Okavango River has been argued to be within sustainable limits (Pallett, 1997), future plans to increase offtake through the Eastern Water Carrier threaten to diminish downstream flows to Botswana (DWARN, 1996). In Botswana’s section of the basin all rivers with the exception of the Okavango are ephemeral. Erratic rainfall and periodic drought have imposed development initiatives that largely focus on increasing access by exploiting the Okavango Delta's perennial supplies. Though Botswana has repeatedly voiced concern over the potential negative effects of increased water use by Namibia and Angola, its own present and anticipated future use has been a major cause of concern. This situation argues for the need to formulate strategies that can enhance sustainable use of this basin's water resources by harmonizing these countries' varied interests.

4. Conceptualising hydroconflicts

While lack of adequate hydrological data continues to undermine the formulation of collective water distribution strategies by hindering the adoption of effective sharing arrangements, lack of institutional structures capable of harmonizing the varied interests of the three countries and non-coincidence of state interests aggravates the situation. Because collaboration entails voluntary surrender of sovereign claims Namibia and Botswana are obliged to compensate Angola for losses associated with collaboration. Reluctance to do so and lack of objective criteria to guide the determination of such compensation have tended to encourage unilateral claims of vaguely defined shares of the Okavango basin's transboundary water resources. In the absence of mutually agreeable distribution criteria, collaboration remains difficult. Although the Okavango River Basin Commission has been put in place to promote co-management, it operates in a vacuum because it has no mandate to enforce water distribution and conflict resolution procedures (Giordano and Wolf, 2003) and remains severely constrained by bureaucratic impedance and reluctance by government departments to move toward integration and to share information (Swatuk, 2008). Conflict over this basin's transboundary water resources can be analysed by applying Game Theory to mathematically model compromise resource sharing strategies. Game Theoretic modelling comprises a number of players who may have, false understanding of each other's preferences, misleading articulation of options available to other players, incomplete knowledge of all the other game players, misunderstandings based on misunderstanding the perceptions of others and lack of unanimity concerning group preferences and options (Okada et al., 1985).

The technique is capable of handling intransitive preferences when modeling coalitions and has been applied to wide ranging disputes that involve players with different interests and options (Aumann et al., 1995). The possible actions are *options* that can be adopted to form *strategies* designed to enhance realisation of preferred *outcomes*. In the case of the Okavango basin, a water crisis is the most unfavourable of all possible outcomes. For Botswana and Namibia, the survival strategy is to ensure that Angola's consumption is minimized but Angola is unlikely to compromise its interests in the name of collective partnership without some form of compensation. This situation can be visualized as a trilateral conflict which is characterised by power variances that are weighted to give a configuration in which (A) is stronger than each of its partners (B and C) that are of equal strength though (A) is weaker than B and C combined. In equation form, this relationship can be stated as: $A > B = C$ but $A < B + C$. By substituting A, B and C for this basin's three states, the following constructs are possible:

A = Angola: most powerful by virtue of its control of the basin's principal sub-catchment.

B = Namibia: intermediate influence but less powerful than A because of vulnerability to strategy formulation by A and B.

C = Botswana: very little influence because of its downstream position.

Under these circumstances cooperation is difficult because:

(a) Coalition between (A) and (B) or (C) undermines the isolated player.

(b) A's overwhelming control over water resources implies domination of its coalition partner.

(c) Neither B nor C would voluntarily undertake a subservient partnership with A.

This configuration tallies with differential advantages that can accrue to Angola, Namibia and Botswana on the basis of asymmetries in runoff contribution (Table 1) and water demand (Table 2) both of which justify most of the sharable water for Angola. If absolute hydrography and demand are used to guide allocation, Namibia and Botswana get marginal proportions. The implication of this scenario is that collective action is difficult to achieve because of differential gains. If geographical endowment and demand are considered, the following permutation: $A > B > C$ provides a matching correspondence. By substituting A, B and C for individual states, Angola emerges as the most powerful while Namibia is accorded a more powerful position than Botswana.

This permutation does not improve the scope for cooperation because:

(a) Angola's dominance still distances the other partners from committed cooperation.

(b) A coalition strategy between Namibia and Botswana is likely to estrange Angola.

(c) Comprehensive partnership is constrained by difficulties in achieving optimal conditions that cater for all members' different interests and expectations.

5. Model application: conflict versus cooperation

Two scenarios are presented to illustrate the adaptability of the model and its applicability under situations with a) sufficient and b) insufficient information.

5.1 Scenario with sufficient information

Within the context of mutual interdependence co-management of the basin's water resources requires high levels of commitment and substantial sacrifice of self-interests. Simplistic sharing on the basis of runoff contribution (Table 1) and/or demand (Table 2) does not create a level ground for negotiating agreeable criteria. To rationalise distribution, proportions claimable by individual countries can be expressed in the form of aggregate percentage scores that capture what each state is entitled to on the basis of resource endowment and demand (Table 3).

Table 3 Aggregate seed-matrix scores derived from runoff contribution and water demand

Basin state	**Angola**	**Namibia**	**Botswana**	**Total**
Runoff contribution	94.50	2.60	2.90	100
Water demand as percentage of total supplies	59.70	22.50	17.80	100
* **Aggregate percentage: [demand + runoff] ÷ 2**	**77.10**	**12.55**	**10.35**	**100**

* This percentage represents the proportion of the basin's water resources each country would get if distribution was to be exclusively based on the logic of runoff contribution and demand.

This aggregation allows antagonistic relationships to be decomposed into a framework of analysis/ interaction comprising: a) Fate Control, b) Reflexive Control and c) Behaviour Control. Fate Control (FC) is the proportion of benefits a player can get that is dependent upon/influenced by the action/s of its opponents (Kelley and Thibaut, 1978). With RC, individual states have independent control over the payoffs/rewards accruing to them regardless of their commitment/s to partnership. RC is the degree to which an actor can influence its payoff by its own choice of strategy regardless of the strategy chosen by its opponent/s. Behaviour Control (BC) involves situations where an actor's receipts are only realisable through joint or interdependent actions and represents situations in which individual actors adjust their behaviour in tandem with the expectations of all partners involved (Kroll, 1993). The matrix in Table 4 provides a game-theoretic exposition of the configuration of resource use decisions and the distribution of benefits/penalties when FC and RC dictate patterns of cooperation. Each country/player's degree of control lies in its ability to choose between strategies S_1 and S_2.

Each strategy has two options (o_1 and o_2) that offer different payoffs. All actors' choices are restricted to one set of strategies that pay differently. The weights used for initial score allocation to strategies by each country reflect different degrees of potential control/influence that are determined by hydrography and demand (Table 3). These variations in water endowment and demand can be mathematically represented without prejudice as long as the transitivity depicted by the A > B > C permutation described under sub-section 4 is observed in the allocation of initial scores. Though runoff contribution and demand can independently provide a similar basis for score allocation, mean scores of both (Table 3) enhance analytic tractability by making the permutations more robust. The initial scores in the seed matrix in Table 4 are allocated on the basis of the aggregate percentages shown in Table 3 (77.1, 12.55 and 10.35 rounded off to the nearest whole number i.e. 77, 13 and 11) for Angola, Namibia and Botswana respectively with the relative degrees of control (Reflexive, Fate and Behaviour control) each country is able to obtain from each strategy (S_1o_1 and S_2o_2) being derivatives of the scores in the seed-matrix cells.

Table 4 Game theoretic conflict-coordination scenarios for transboundary water use in the Okavango basin by Angola, Namibia and Botswana with sufficient information

		Seed Matrix Game Scores			**Average weights for Reflexive Control (RC), Fate (FC) and Behaviour Control (BC) for strategies S_1 and S_2**							
		o_1	o_2		RC			FC			BC	
Actor (A): Angola	S_1	27	20	=	4.25	4.25	+	-7.75	-7.75	+	N/a	N/a
	S_2	18	12		-4	-4		-3.75	-3.75		22.75	22.75
Actor (B):	S_1	3	2	=	-0.75	-0.75	+	11.25	11.25	+	N/a	N/a
	S_2	5	3		0.75	0.75		7.25	7.25		-4	-4
Actor (C): Botswana	S_1	3	1	=	-0.75	-0.75	+	11.75	11.75	+	N/a	N/a
	S_2	4	3		0.75	0.75		7.75	7.75		-5	-5

Total Game Payoffs

$S_1 = (47+5+4) = 56$
$S_2 = (30+8+7) = 45$

Actor's total control by control and strategy type

	RC		FC		BC	
	RCS_1	RCS_2	FCS_1	FCS_2	BCS_1	BCS_2
Angola	8	-8	-15.5	-7.5	N/a	45.5
Namibia	-1.5	1.5	22.5	14.5	N/a	-8
Botswana	-1.5	1.5	23.5	15.5	N/a	-10

S_1 Strategy 1: Conflict.
S_2 Strategy 2: Coordination.

The greatest benefits accrue to Angola, followed by Namibia. Botswana gets the lowest by virtue of its disadvantaged position.

RCS_1 = Reflexive control for strategy 1; RCS_2 = Reflexive control for strategy 2.
FCS_1 = Fate control for strategy 1; FCS_2 = Fate control for strategy 2.
BCS_1 = Behaviour control for strategy 1; BCS_2 = Behaviour control for strategy 2.
N/a: In practical situations, these values cannot be calculated because cooperation precludes conflict.

The next sub-sections (sub-sections 5.1-5.3) explain how the scores on RC, FC and BC shown in Table 4 were calculated.

5.1.1 *Reflexive Control*

A's degree of control is calculated from the average payoff it receives from choice of strategy, either S_1 or S_2.

A's average payoff for: Cells linked to strategy S_1 is: $S_1o_1 + S_1o_2 = (27 + 20)/2 = 23.5$

Cells linked to strategy S_2 is: $S_2o_1 + S_2o_2 = (18 + 12)/2 = 15$

$\therefore$ The value of strategies $S_1o_1 + S_1o_2$ relative to strategies $S_2o_1 + S_2o_2$

$= 23.5 - 15$

$= 8.5$

Strategy S_1 is therefore superior to S_2 by 8.5 units. Assuming rational behaviour, maximisation of payoffs compels A to choose strategy S_1. A's Reflexive Control (RC) or the proportion of total benefits realisable by choice of strategy is 8.5. The average from this value (8.5/2) is placed in A's cell-arrays for the same strategy under the appropriate RC column. No matter what strategy B and C choose, A receives 8.5 units more payoff from strategy S_1 than S_2. Since A's payoff is dependent on its own choice of strategy, its RC is 8.5. RC values for Botswana and Namibia are likewise calculated and placed in their respective cells. If conflict prevails Botswana and Namibia lose while Angola benefits. However, if retaliatory strategies are adopted Botswana and Namibia will choose strategy S_2. Using the same procedure to calculate RC weights for Namibia and Botswana yields combined payoffs of 56 and 45 for conflict and cooperation respectively. So far, the insight revealed by the game which the raw seed matrix scores fail to show is that Botswana and Namibia benefit under cooperation since their RC increases while Angola is disadvantaged.

5.1.2 *Fate Control*

A's Fate Control (FC) is the degree to which its payoff is determined by the strategies adopted by B and C irrespective of what A does, the higher this number, the greater the control and vice-versa. The assumption determining the outcome is that B and C can strategise unilaterally. To calculate A's FC, we need to calculate the average payoff for B and C. Following the logic in A's selection of strategy, B and C will be compelled to choose the highest paying strategy and both choose S_2.

$\therefore$ B's average payoff for strategy S_2 is: $(5 + 3)/2 = 4$

C's average payoff for strategy S_2 is: $(4 + 3)/2 = 3.5$

1] A's FC is: = (B's average payoff + C's average payoff) – A's average payoff

$= (4 + 3.5) - 23.5 = -16$

2] B's FC is: = (A's average payoff + C's average payoff) – B's average payoff

$= (23.5 + 3.5) - 4 = 23$

3] C's FC is: = (A's average payoff + B's average payoff) – C's average payoff

$= (23.5 + 4) - 3.5 = 24$

At this stage, the game has revealed two additional characteristics of the relationship. The negative -16 units show that Angola is independent of strategy formulation by Botswana and Namibia while 23 units and 24 units indicate Angola's overwhelming/absolute control over these countries. A different picture emerges if they all cooperate. If Angola cooperates, Botswana and Namibia still choose strategy S_2, and Angola does the same so that:

1] A's FC is: = (B's average payoff + C's average payoff) – A's average payoff
= (4 + 3.5) – 15 = -7.5

2] B's FC is: = (A's average payoff + C's average payoff) – B's average payoff
= (15 + 3.5) – 4 = 14.5

3] C's FC is: = (A's average payoff + B's average payoff) – C's average payoff
= (15 + 4) – 3.5 = 15.5

If the three countries cooperate, the proportion of benefits Namibia and Botswana get dependent on Angola's choice of strategy goes down though their dependence on Angola still persists.

5.1.3 *Behaviour Control*

Angola's Behaviour Control (BC) is the degree to which by adopting a specific strategy, it can influence Namibia and Botswana's incentives to adopt the same strategy and '*is calculated by determining the value needed to make* RC + FC + BC *equal the original payoff in each cell*' (Kroll, 1993: 327). The following calculations yield the necessary values required to satisfy this condition when cooperation prevails.

1] A's BC (the unknown x value) for strategy $S_2 = (RCS_2 + FCS_2 + x) = 30$
$= (-8) + (-7.5) + x = 30$
$x = 45.5$

2] B's BC (the unknown x value) for strategy $S_2 = (RCS_2 + FCS_2 + x) = 8$
$= 1.5 + 14.5 + x = 8$
$x = –8$

3] Botswana's BC (the unknown x value) for strategy $S_2 = (3 + 2) – (1 + 4) = 0$
$= 1.5 + 15.5 + x = 7$
$x = –10$

The score 45.5 shows that Angola's choice of strategy substantially influences strategy selection by Namibia and Botswana whose negative scores indicate lack of direct influence on Angola's choice of strategy. Overall, the proportion of total benefits accruing to individual states determined by the choice of strategies by co-partners is biased against Botswana. Namibia and Botswana's combined negative FC values of -15.5 and -7.5 for conflict and cooperation respectively indicate that their choice of strategy does not affect Angola's choice of strategy. Under unilateral behaviour (no cooperation and/or pure conflict) the proportion of benefits accruing to Angola dependent on choice of strategy by Namibia and Botswana is zero (0). The latter can only get the surplus Angola is unable to use. When conflict prevails, Angola will choose the most rewarding strategy (S_1) compelling Namibia and Botswana to go for strategy S_2. Conflict yields short-term maximum returns for Angola and a higher combined payoff of 47 i.e. 27+20.

However, if they cooperate, Angola forfeits some potential benefits by allowing water at its disposal to flow to Namibia and Namibia which does the same for Botswana while Botswana in turn leaves some for ecosystem services hence cooperation (strategy S_2) yields less for all but the collective dividend is enhanced conservation from the excess water (56-45) committed for the sustenance ecosystem processes. Since Angola's generosity under cooperation allows Botswana and Namibia to gain, the benefactors should compensate Angola by merely returning some of the benefits from what Angola allowed to trickle down. If unilateral choice of strategy is given precedence over cooperation, Angola's full exploitation of its development potential implies more aggressive exploitation of the headwater resources of the Okavango River. If this materialises, then Namibia and Botswana might find themselves confronted by reduced water supply situations. Since it is inevitable that Angola will increase water use as demand increases, Namibia and Botswana need to encourage Angola to minimise use of its water resources at levels that may lead to significant reduction in downstream flows.

If Angola is to forfeit some of its development opportunities, such a sacrifice would warrant similar commitment by Namibia and Botswana. In the matrix game above, collaborative initiatives under the Behaviour Control tandem (cooperation) show that Angola will lose 17 units i.e. (47 - 30 = 17). Namibia and Botswana gain 3 units each i.e. 8 - 5 and 7 - 4 respectively. Intimate reflection on the logic involved suggests that Angola can be motivated to cooperate by using the outcome of this game to optimise distribution.

5.2 Scenario with insufficient information

Where comprehensive information is lacking, the model can still be applied as a stopgap measure to facilitate distribution as detailed information is being compiled. Table 5 shows results of a modeling exercise on the basis of percentage distributions of population by sub-catchment in Angola (76%), Namibia (13%) and Botswana (11%).

Table 5 Game theoretic conflict-coordination scenarios for transboundary water use in the Okavango basin by Angola, Namibia and Botswana with insufficient information

		Seed Matrix Game Scores			**Average weights for Reflexive Control (RC), Fate (FC) and Behaviour Control (BC) for strategies S_1 and S_2**							
		o_1	o_2		RC			FC			BC	
Actor (A): Angola	S_1	26	20	=	4	4	+	-7.75	-7.75	+	N/a	N/a
	S_2	18	12		-4	-4		-3.75	-3.75		22.75	22.75
Actor (B):	S_1	3	2	=	-0.75	-0.75	+	11.25	11.25	+	N/a	N/a
	S_2	5	3		0.75	0.75		7.25	7.25		-4	-4
Actor (C): Botswana	S_1	3	1	=	-0.75	-0.75	+	11.75	11.75	+	N/a	N/a
	S_2	4	3		0.75	0.75		7.75	7.75		-5	-5

Total Game Payoffs

$S_1 = (46+5+4) = 55$
$S_2 = (6+7+6) = 45$

Actor's total control by control and strategy type

	RC		FC		BC	
	RCS_1	RCS_2	FCS_1	FCS_2	BCS_1	BCS_2
Angola	8	-8	-15.5	-7.5	N/a	45.5
Namibia	-1.5	1.5	22.5	14.5	N/a	-8
Botswana	-1.5	1.5	23.5	15.5	N/a	-10

S_1 Strategy 1: Conflict.
S_2 Strategy 2: Coordination.

The greatest benefits accrue to Angola, followed by Namibia. Botswana gets the lowest by virtue of its disadvantaged position.

RCS_1 = Reflexive control for strategy 1; RCS_2 = Reflexive control for strategy 2.
FCS_1 = Fate control for strategy 1; FCS_2 = Fate control for strategy 2.
BCS_1 = Behaviour control for strategy 1; BCS_2 = Behaviour control for strategy 2.
N/a: In practical situations, these values cannot be calculated because cooperation precludes conflict.

Comparative assessment of results from the two scenarios shows marginal variation. The only difference relates to total game payoffs, 56 for the sufficient information scenario (Table 4) and 55 for the insufficient information scenario (Table 5). This close tie illustrates the robustness of the model and the extent to which it is capable of handling situations with marginal information.

5.3 *Concluding remarks*

The important insight from this analysis is that in areas characterized by asymmetries in resource endowment and conflict over access, Game Theoretic modeling can provide an objective basis for rational distribution. By revealing differential scales of advantage and disadvantage in the form of losses and gains associated with conflict and cooperation, game theory offers tremendous scope for objective determination of compensations that can be offered by water-poor countries/areas to their water-rich neighbours to offset losses associated with cooperation and we invite and urge those interested to explore the usefulness of this proposed model to the in resolving conflict over contested transboundary water resources.

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