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Kalai-smorodinsky bargaining solution for the logone river basin water allocation

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Abstract

This paper focuses on methods to resolve the ongoing conflict between users in the logone Basin, over water sharing. It addresses the problem by using the cooperative negotiations games framework. It identifies difficulties of choosing the most suitable solution to the Nash bargaining problem under independence of irrelevant alternatives that may obstruct negotiations on water allocation. A positive mathematical programming is applied to find the net agricultural benefit of the players involved in the competition about water management. In the second time the Kalai-Smorodinsky solution is recommended as optimal in the concrete situation because it considers efficiency of water use of the involved users and its sequential use leads to a Pareto-optimal outcome.

Keywords: Logone basin, Kalai-Smorodinsky, conflict, negotiation.

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1-Introduction

Drought is a very serious problem in the Sahelian area; climate change and demography accentuate the water scarcity in that area. This situation leads to conflicts between uses that share the same river and have conflictual interest (Hipel and al.1997; Wang and al. 2003; Fang and al. 1998). The logone river basin faces these difficulties characterized by the scarcity of water and the ongoing conflict between the users. The logone river basin has been a field of many confrontations over water allocation problem. In May 1965 Cameroonians fishers and Chadians fishers confronted themselves about water allocation; in 1974, Cameroon and Nigeria settle the irrigation system by embezzling the water of the logone river (CBLT, 2020); that situation unpleased to Chad and accused Cameroon and Nigeria for this initiative. In June 2018, confrontation between farmers made 86 deaths. Since users are rational and take decision, game theory tools are very important to solve these ongoing conflicts in the logone river basin. The opposition of conflicts obviously lead to adopt strategies over the water usage. That is why the objective of this paper is to apply game theory tools to resolve conflicts over the water allocation problem in the logone river basin. Several studies have applied game theory to resolve water conflict. Rogers (1969) applied game theory approach to solve conflicts between Indian and Pakistan in the Ganges-Brahmaputra river basin. Theirs results shows that cooperation is suitable than non-cooperation strategies. Rogers (1991) exposed the cooperative game theory to share the Columbia river basin water between USA and Canada. His results show again that cooperation improve social welfare. Just and Netanyahu (1998) discussed about difficulties relative to the formation of coalitions in the transboundary river basin. These difficulties concern the asymmetric information between users that have conflictual interest. Madani and Dinar (2011) made a study on the water management conflicts in the Nil basin. At the end of their study, they showed that cooperative game theory tools can resolve conflicts over water allocation. For them, conflict is the result of contradictory interest among Egypt, Sudan, Ethiopia and other countries. In the same logic, Dinar (2004) ran a cooperative game theory analysis over the water resources management. He argues that competition over water leads to conflicts; he urges to cooperation over the water allocation. Houba and al. (2012), agreed that negotiation over the Mekong river basin could lead to optimal water management by implementing cooperation. In the meantime, Shreider and al. (2007) in their works, used game theory approach to model the collective strategies in the Hop-Kins river basin. For them, game theory is widely used as mathematical tools to understand how rational human-being take the decision in the framework of conflicts. Saleth (1996) uses the Nash negotiation solution to cope with conflicts over water allocation. He suggests that the water market right could be rigid. Le

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Marquand (1977) exposes a general conceptual framework to understand the international cooperation concept by considering hydrologic, economics and politics aspects. Maya and Ngouhouo (2018) applied the cooperative game theory to resolve conflicts in the logone river basin; he found that cooperation lead to fair water allocation and improve social welfare. Jisi and al. (2018) used the asymmetric Nash bargaining solution in the Huaihe river basin to prove that cooperation leads to optimal utility. Degefu and al. (2016) developed the cooperative negotiation game to resolve the water allocation conflict in the Nil basin. In addition, Dlouhy and Fiala (2009) looked for resolving conflicts over the water sharing problem by using the cooperative game theory.

This paper presents the Kalai-Smorodinsky negotiation solution for resolving conflicts among the users in the logone river basin. the contribution of this paper is that we introduced the axiom of monotonicity among the players; that is because if the amount of resource increase, the situation of neither player will worsen. that is what Maya (2018) ignored and the collective rationality is not easy to be implemented; that is why Kalai-Smorodinsky bargaining is suitable in this case to resolve conflicts in the logone river basin. Four players (regions) are involved in the game. The game concerns only farmers that maximize their utility function according to their respective area. In the first time, each player act alone in the framework of non-cooperative game theory; then we consider the framework that players bargain among them. The outline of the paper is follows: In section 2, we describe the mathematical methodology; and the case study will be discussed in section 3; the results are presented in section 4; and section 5 concludes the paper.

2-Methodology

Kalai (1975) suggested an axiomatic bargaining solution that differs from that of Nash (1950) with a strong scientific foundation in economics. Assume that there are 4 decision makers. A bargaining solution is a pair (F, d) where $F \subseteq \mathbb{R}^4$ is a compact convex set, $d \in F$, and there exists, $f \in F$ such that $f_i > d_i$ for i=1, 2,…,4. F denote the feasible space and d the disagreement point. Kalai-Smorodinsky concluded that this solution selects the unique solution that satisfies the monotonicity axiom. the Kalai-Smorodinsky (1975) solution is given by:

$$\frac{s_i - d_i}{s_i^* - d_i} = k$$

S_i is the Kalai-Smorodinsky payoff

s_i^* is the maximal pay-off reached by a player when the others get the disagreement utilities.

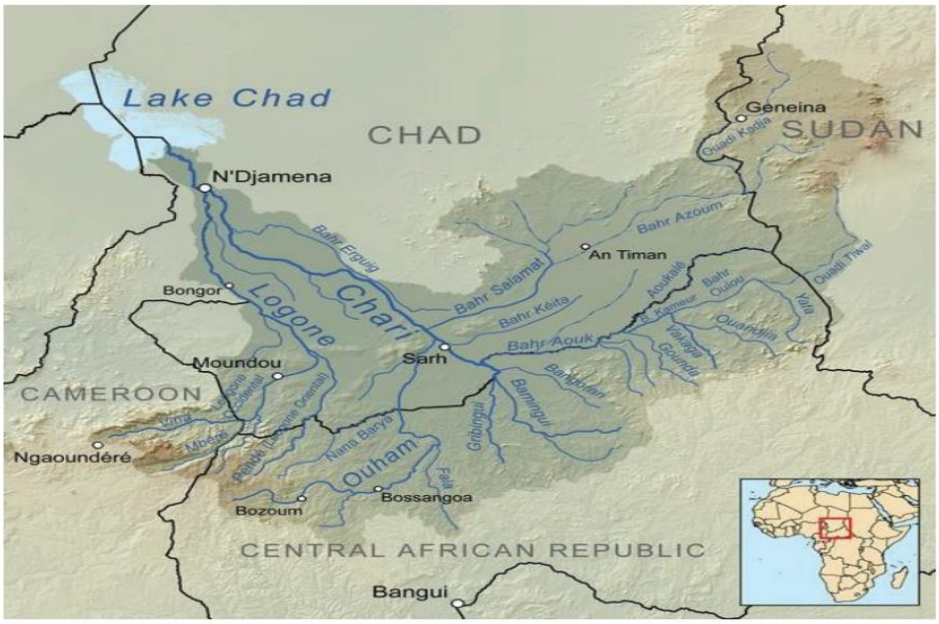
K is constant.

d_i is the disagreement point of player i

3-Case study

The logone river originates in the Adamaoua mountains and flows toward the Chari river in N'djamena after it travelled Doba, Moundou, Lai and bongor towns. The logone is formed by two rivers coming from Adamaoua in Cameroon: The Vina and the Mbere. It is 960 km long. The Maga dam was built on the river in 1974 to enhance the local economic activities. It provides water to many towns in Chad and Cameroon for irrigated agriculture, domestic and industrial consumption. The gross agricultural area of the basin is 2893 ha for Kousseri, 6306 ha for Yagoua, 5347 ha for Maga, 2104 ha for Sategui-Daressia and 943 ha for Bongor. These agricultural areas are very crucial for the live of the population in the region. In addition to agricultural consumption, the logone river supplies water to other sectorial economic. Because of the limited water supply, there is an on ongoing conflict among the water users. The mains agricultural activities are the culture of maize, onion, rice, tomatoes and vegetables. In this paper we consider four intensive agricultural municipalities that are Mayo danay, Kousseri, Bongor and Sategui daressia. Our data is collected with the cooperation of CBLT, SDEA, SEMRY and the MINEE.

Figure 1 : the location of logone river basin



Source :(CBLT, 2020)

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3.1 Calculating the payoff of players

3.1 Calculating the payoff of players using characteristic function

The net agricultural benefit is defined as in Howitt (2006) and Maya and Ngouhouo (2018) by:

$$Max\ \pi = \sum_i \sum_j \left[p_{zi} \left(\mu_{zi} \left[\sum_j \beta_{zij} x_{zij}^{\gamma_i} \right]^{\vartheta_i/\gamma} \right) - \left(\left(\alpha_{zi} + 0{,}5\theta_{zi} x^2{}_{zi,land} \right) + \sum_{j \neq land} \omega_{zij} a_{zij} \right) \right] x_{zi,land} \qquad 3$$

Subject to

$$\sum_i a_{zij} x_{zi,land} \leq b_{zj} : \forall z, j = \{\text{land, water, labour}\} \qquad 4$$

$$\sum_t x_{z,water,t} \leq \xi b_{z,water}\ \forall\ z \qquad 5$$

$$\sum_t x_{z,labour} \leq \xi b_{z,labour} \forall\ z \qquad 6$$

Subscripts z, i, and j denote respectively the zone, farmer and crop.

p_{zi} is the unitary selling price of crop i in the zone z

The decision variable x_{zi} represents the amount of land to crop i in the zone z.

ω_a gives the cost variable mean per acre of land.

Parameter b is the maximum quantity of resource j.

v_i is the parameter associated with the return to scale

γ is given by $\sigma - 1/_{\sigma}$ where σ is the elasticity of input substitution.

We assume here that farmers operate under constant returns to scale and that the elasticity of input substitution is 0,25.

And the characteristic function for full cooperation is defined by:

$$v(N) = Maxf^N = \sum_i \sum_j \left[p_{zi} \left(\mu_{zi} \left[\sum_j \beta_{zij} x_{zij}^{\gamma_i} \right]^{\vartheta_i/\gamma} \right) - \left(\left(\alpha_{zi} + 0{,}5\theta_{zi} x^2{}_{zi,land} \right) + \sum_{j \neq land} \omega_{zij} a_{zij} \right) \right] x_{zi,land} \qquad 7$$

S.t

$$\sum_i a_{zij} x_{zi,land} \leq b_{zj} : \forall z, j = \{\text{land, water, labour}\} \qquad 8$$

$$\sum_t x_{z,water,t} \leq \xi b_{z,water}\ \forall\ z \qquad 9$$

$$\sum_t x_{z,labour} \leq \xi b_{z,labour}\ \forall\ z \qquad 10$$

The parameters and variables are defined above.

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4-Results

4.1 Kalai-Smorodinsky solution

As in table 1, the payoff of player S1 increased from 5,33 to 5,612; S2 went from 4,25 to 4,7; S3 increased his payoff going from 3,33 to 3,737 and S4 increased from 3,5 to 3,764 (see table 1). We noticed a significant improvement of the players utilities. Globally, we moved from disagreements points to find new equilibrium (Nash solution) that satisfies Nash's axioms. Graph 1 clearly shows the gap between disagreement point and Kalai-Smorodinsky solutions (graph 1). These results are on line with that of Melnikovova (2017) who demonstraded that the Kalai-Smorodinsky solution was suitable to negotiation problem. Other authors also found the same results (Ansink and Houba, 2014; Cernik and Valencik, 2016)..

4-2 improved gains

This table (table 2) shows us the effective difference when the players bargain. We also got it in percentage.

In conclusion bargaining improves the utilities of players. In example, S1, S2, S3 and S4 improved their utility respectively by 5,29%, 10;58%, 12,22% and 7,54% (see table 2).

These results joint those of (Ambec and Ehlers, 2008; Cernik and Valencik, 2016; Cervenka and al., 2015; Eleftheriadou and Mylopoulos, 2008; Dlouhy and Fiala, 2009).

5-Conclusions

This study used the cooperative game theory model to analyse a water conflict in the logone river basin among farmers. The mathematical tool used is the Kalai-Smorodinsky bargaining solution. This approach attempts to resolve the problem of optimal water allocation under monotonicity 'axioms. At the end, our results demonstrated that the Kalai-Smorodinsky bargaining solution can be applied to resolve water conflicts and the authority can then implement suitable policies that urge to coordination.

Table 1 : the Kalai-Smorodinsky solutions

Joueur	K-S
s_1	5,6775
s_2	4,5975
s_3	3,6775
s_4	3,8475

Source: author

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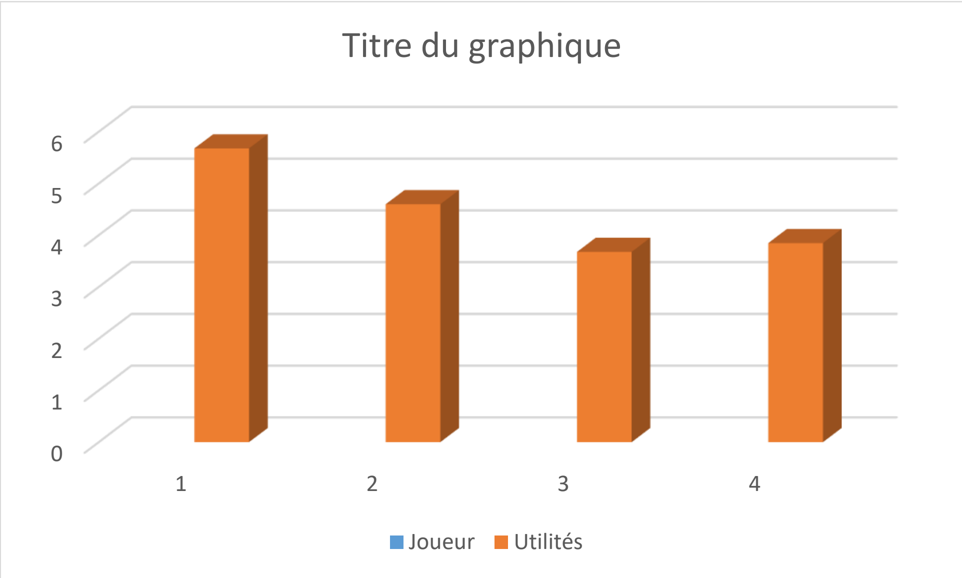
Table 2 : improved gain in percentage

Joueur	Différentiel	En pourcentage
s_1	0,282	5,29
s_2	0,45	10,58
s_3	0,407	12,22
s_4	0,264	7,54

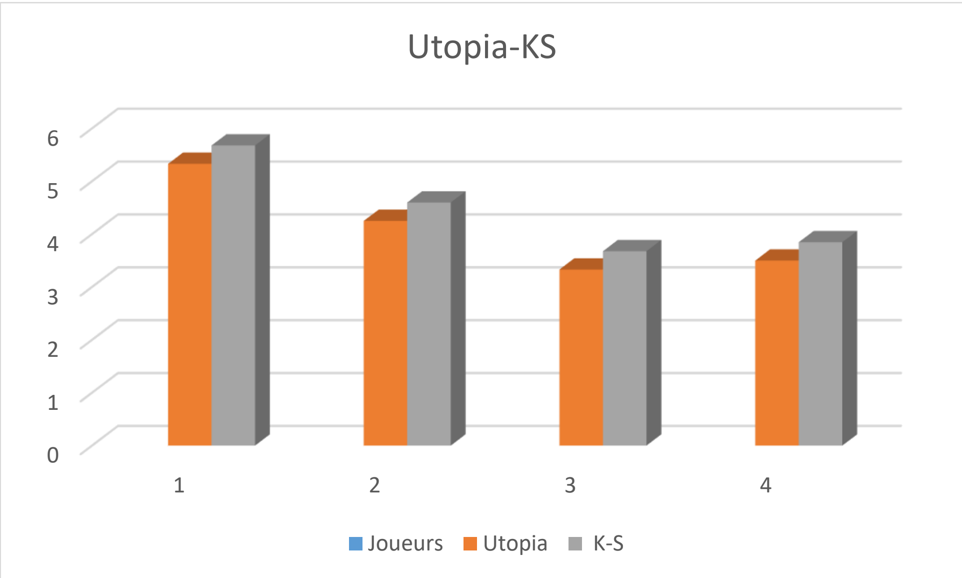
Source: author

Figure 2 : the distribution of Kalai-Smorodinsky



Source: author

Figure 3 : the distribution of improved gain



Source: author

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