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A scarcity value based explanation of trans-boundary water disputes: the case of the Cauvery River Basin in India

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Abstract

The paper is an attempt to interpret trans-boundary water disputes with the help of scarcity value, which is the value that could have been generated if the limit on water availability could be relaxed by one unit. Scarcity value measures the degree of deprivation and creates the basis for disputes. This hypothesis has been applied in this paper to the disputes over water use for irrigation in the Cauvery basin between the states of Karnataka and Tamil Nadu in South India. On the basis of the historical data for the area under paddy cultivation in the two states, the paper shows that such disputes are not clearly based on physical scarcity of water but are a temporal coincidence of demand based on scarcity value. This means that enhanced supply would not be the correct approach to the resolution of disputes. New economic instruments based on scarcity value may provide a more objective picture of the disputes and hence help in their amicable resolution.

Keywords: Demand management; Scarcity value; Supply augmentation; Trans-boundary water conflicts; Water scarce economies

1. Introduction

Trans-boundary water disputes have emerged as an increasingly important factor in hydropolitics at various spatial levels. They relate to politics and conflicts at the level of a village as much to the economic development of nations and regions sharing common waters. Theoretical analysis of trans-boundary water disputes conflicts, accordingly, has become an essential part of development studies. The present paper is guided by this idea. The Malthusian creed of hypothesising “scarcity induces disputes” as an explanation of trans-boundary water conflicts can be reached from the extensive database of the existing literature on water conflicts in particular and environmental conflicts in general (Westing, 1986; Homer-Dixon, 1991, 1994; Gleick, 1993; Richards & Singh, 1997; Hall & Hall, 1998; Rowley, 1998; Janakarajan, 2003). The literature supports the validity of such a notion in

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the cases of disputes over various other competing uses of water, namely inter-sectoral allocations and interstate or international allocations (e.g. Bandyopadhyay, 1995; Bandyopadhyay & Perveen, 2004; Flessa, 2004).

From the policy perspective, planners and decision makers have to address scarcity on the various spatial and temporal scales. This necessitates the availability of a holistic tool for the management of water systems that would be relevant for the various spatial levels, to determine priorities for action and to monitor progress towards the targets. Quantified indicators to benchmark availability of water help planning, and even management, of water resources in a better way, when progress is measured in more concrete and quantitative ways (Molle & Mollinga, 2003). The development of such indicators has been initiated over the last two decades.

The initial indicators mainly followed the Malthusian tradition of defining water scarcity in terms of annual per capita availability of the resource (e.g. Falkenmark & Widstrand, 1992; Raskin *et al.*, 1997). Subsequently, improved indicators were developed by incorporating future demand scenarios (e.g. Seckler *et al.*, 1998), highlighting sectoral allocations including allocation for the environmental sector (e.g. Salameh, 2000; Feitelson & Chenoweth, 2002), putting forth alternative social resources to adapt to water scarcity (e.g. Ohlsson, 1998; Turton & Ohlsson, 1999), propounding theoretical models linking economic development and environmental capital (e.g. Allan, 1996; Turton, 1997), and embodying the society–scarcity nexus (e.g. Molle & Mollinga, 2003). Some other interesting approaches involve a grid approach (Meigh *et al.*, 1999), a river basin approach (Alcamo *et al.*, 1997) or a mix of basins and administrative units (Amarasinghe *et al.*, 1999) and composite indicators of scarcity (e.g., Amarasinghe, 2003).

The “Water Poverty Index” (Lawrence *et al.*, 2002; Sullivan, 2002) considers factors of resource availability, access, capacity in terms of income and health and sectoral uses including ecological utilities. The movement from the concept of “water scarcity” to that of “water poverty” is an important step forward, in the sense that conditions of access and information have been given recognition. This relates to situations where high physical availability of the resource exists but improper information and lack of accessibility lead to a scarcity situation. With knowledge becoming more and more important with time, such problems could become even more widespread in future years.

With this background of the emergence of the various indicators for water scarcity, the hypothesis “scarcity induces dispute” will be analysed in this paper. Considering the “supply side” indicators, it can be found that, for example, nations in the Jordan Basin, namely, Israel and Jordan, are water scarce. According to the Water Barrier Scale (Falkenmark *et al.*, 1989), Israel moved “beyond water barrier” in 1982 (Jobson, 1999:11), while Jordan did the same in 1960 (Jobson, 1999:14). According to the IWMI indicators, both these nations belong to those with the highest degree of water scarcity, considering present and future conditions. At one time, a situation of conflict over water existed between these two nations. However, effective management of the available water resources, lately, has resulted in the two nations moving towards peaceful hydropolitics, despite the fact that serious problems on other political issues persist in the region. Scarcity indicators have not yet captured the imagination of policy makers. According to Ghosh (2005), the prevailing conflicts in the river basins of India like Cauvery, Krishna, Narmada and Godavari have not reached the level of intensity that existed at one time between Israel and Jordan. Nevertheless, these river basins are facing regular disputes and conflicts between and among the trans-boundary stakeholders (Richards & Singh, 1996; Ghosh, 2005).

The Water Poverty Indicator (WPI) has been partially successful in explaining such issues, but only partly. This has happened for two reasons. First, the WPI does not recognise the role of *virtual water imports*[1] in mitigating water conflicts. Second, the WPI has not been used at the river basin level. In order to implement it at that level, data on a larger number of variables is needed (Ghosh, 2005). Thus, the existing scarcity indicators are not able to provide a comprehensive basis for the hypothesis "scarcity induces disputes". The present work addresses this question that arises from such questions about the validity of the hypothesis. Under such circumstances, this paper is a quest to identify a more fundamental basis and indicator for the disputes.

Economics is an important factor behind conflicts for three reasons. First, when the nature of the disputes over water is looked at in depth, it is found that in a majority of cases, the contribution of water to competing economies has been the prime cause of disputes. In the case of India, agriculture being the largest consumer of water, the majority of trans-boundary water conflicts occur because of the conflicting agricultural water needs of co-riparians. Of course, with the emerging high rate of industrial growth in India, this picture may change. Second, an objective explanation of water conflicts would be of help in providing a suitable institutional framework for their resolution at various levels. This necessitates an economic analysis of the conflicts. Third, water is scarce and needs to be allocated among competing ends for which economics provide useful tools (Robbins, 1932).

In this paper an economic variable termed the *scarcity value* is used and it is proposed that it is the scarcity value that induces disputes. The scarcity value is the value of scarcity, or more precisely as the *value loss due to scarcity at the margin of production* at a specific time. The theoretical basis of scarcity value is first explained and then the validity of the tool is assessed in respect of water disputes over the Cauvery river waters between the states of Karnataka and Tamil Nadu in India. A dispute is expected to emerge at a specific time, if the scarcity value of water is simultaneously high for the stakeholders. This notion has been referred to in the literature in some other contexts (e.g. Tsur *et al.*, 2004). However, the work of Chowdhury (2005) has some similarity with the way scarcity value has been perceived in this paper, although Chowdhury's approach is based on a translog production function. Chowdhury does not go beyond estimating scarcity value and does not embark on the policy implications of such a framework. This paper uses a Cobb–Douglas production function and goes on to explain water dispute situations on the basis of scarcity value.

Section 2 of this paper presents the theoretical basis of the notion of scarcity value and defines it. Section 3 presents a scarcity value-based explanation of the inter-state water disputes in the Cauvery Basin. In this case, the intensity of the conflict between the two states of Karnataka and Tamil Nadu increased with a non-diminishing scarcity value for increased water use by a certain crop of paddy, which occupies the maximum acreage in the basin. Section 4 attempts to discern the factors of non-responsiveness of the scarcity value of paddy and proposes a few solutions.

[1] Virtual water is the amount of water embedded in final products. If it requires 16 units of water to produce 1 unit of *X*, the virtual water content of *X* is 16 units. The import of one unit of *X* entails import of 16 units of virtual water.

2. Theoretical setting: defining water scarce economy and scarcity value

2.1 The notion of a "water scarce economy"

The analytical framework presented in this paper is based on a few basic postulates. The postulates emerge from consideration of the "purely economic" view of water scarcity and dispute, keeping the social–politico-cultural elements outside the purview. Although the latter have often been very important factors in the emergence of various disputes, for the sake of clearer understanding, the impact of economic factors has been given the sole consideration in this analysis.

On the other hand, the paper has been confined to analysing producers' surplus and does not take into consideration the entire social welfare function which would otherwise have incorporated the consumer surplus. This is for the following reasons:

- 85% of the utilised water resources are being used in production of agricultural crops.
- Even if we look at disputes over water, it is happening because of loss of agricultural production owing to water scarcity.
- As has been evident in most cases (and also the case of Cauvery discussed in this paper), producers are actually responding to increased demand for a water-consuming crop, e.g. rice. A low price for the crop shifts the consumption pattern further towards it vis-à-vis other staples, thereby moving the "market" in its favour. Hence, there is higher incentive for producers to produce more rice that has an "easier" market compared to other crops.

The following postulates are being made:

Postulate 1: Water is only as valuable as the economic returns it yields

This assumption implies that water provides only one-dimensional functions and they are all economic in nature. Water users are assumed to be interested only in the economic return from water, rather than its other important aspects, like ecological and cultural effects. In line with Fisher (1995), the present assertion is that the users' primary interest in water arises from the value it generates for the economy. Hence, communities can be compensated for water loss through monetary compensation or through other replaceable means yielding at least the same value as water yields.

Postulate 2: All other things (including water quality) remaining constant, water from one source is substitutable with water from any other source

This postulate implies that if two states, A and B, share water from source X, then the value of water from source X would diminish for i ($i = A, B$) if it finds Y as another source of water. This assumption is again based on the idea that the sole importance of water is derived from the economic rationale and nothing else. In the process, another postulate, which is an integral characteristic of the definition of water scarce economies, is incorporated.

Definition: A "water scarce" economy is one in which scarcity of water constrains land use.

Postulate 3: Water scarcity constrains land use

According to this postulate, it is assumed that the availability of land is unrestricted in the short run. Hence, new land can be brought under the fold of the production process, if necessary water is available. It is due to the unavailability of water that land cannot be brought into the production process. The quality of land may vary (in terms of fertility index) from place to place and good quality land might be scarce. However, in situations where more agricultural production is being awaited to feed the increasing population, such considerations are not too significant. Hence, although Ricardian rents might arise in the process owing to land differentials, it has been kept out of the purview of this analysis. For a particular crop, therefore, a certain level of availability of water can ensure only a certain amount of land under production. Unless water availability increases, the area under production for the crop under consideration cannot be increased. This leads us to an alternative definition of a water scarce economy.

An alternative definition of a "water scarce" economy is one where water supply augmentation is associated with or leads to increases in cropped agricultural land.

2.2 "Scarcity value" of water in water scarce economies: the theoretical framework

It is scarcity of water that makes economies realise the value of the resource (Fisher, 1995). Since this value arises owing to the constraint on the supply of the resource under consideration, it can be called the *scarcity value* of water. To put it more formally, to an economic agent, the scarcity value of a resource, say water, is precisely the value that water can generate, if the limit on its availability is relaxed by a single unit. In other words, it is that value, which could have been generated at the margin by water, but remains to be realised because of its scarcity.

A hypothetical agrarian water scarce economy is assumed to be encapsulated into an agricultural farm. Water is the only input in the production process and makes up the production function. It is assumed that there is a representative crop grown in the economy. The farmer (or central planner) intends to maximise his surplus return or profit in terms of the input used. With the input being water, the inherent tendency of the profit-maximising farmer would be to use water until the point where his profit is maximised. The symbols used are as follows:

$A \equiv$ area under the representative crop;
$\omega \equiv$ minimum water required per unit of area for the representative crop;
$W \equiv$ total minimum water required for watering the entire area A;
$\bar{W} \equiv$ maximum available water;

This is true for all the crops across various agricultural seasons. The following identity can thus be written:

$$W = \omega.A \tag{1}$$

The production function is as follows:

$$Y = F(W), \quad F_W \geq 0, \quad F_{WW} \leq 0 \tag{2}$$

Incorporating the identity (1) into (2) implies:

$$Y = F(\omega.A) \tag{3}$$

$$\text{Water use can never exceed the maximum available water, } \bar{W}. \text{ Hence : } \omega.A \leq \bar{W} \tag{4}$$

$$\text{In a water scarce economy, the entire water available isused up. Hence : } \omega.A = \bar{W} \tag{5}$$

It is further assumed in this context that for every unit of land, the required minimum water is applied and thus a lower availability of water constrains the use of A. While, from Equation (5), it can always be inferred that A is directly proportional to $\bar{W}$, the value that is yielded by water is also yielded by land. In other words, if the potential value of water is defined as the potential value that it could have yielded in the scenario of availability of an extra unit of water, the same needs to be applied to an extra unit of land. This is because, $(\partial Y/\partial A) = 0$ if $\mathrm{d}\bar{W} = 0$. This implies that even if extra units of land are brought under the fold of the production process, without an extra unit of water on the extra unit of land, nothing can be grown. Thus, area can act as a very good proxy for the amount of water used, or the other way round.

Let the associated cost function for applying water be:

$$C = C(W), \quad C_W \geq 0, \quad C_{WW} \geq 0. \tag{6}$$

The surplus created by the economy is:

$$\pi(W) = P.F(W) - C(W) \tag{7}$$

where P is the price of the representative crop.

In the hypothetical economy, the profit, as expressed in Equation (7) is being maximised subject to the water availability constraint (4). In optimisation terms, this entails the creation of a Lagrangian L in the following form:

$$L(W, \lambda) = P.F(W) - C(W) + \lambda(\bar{W} - W) \tag{8}$$

where λ is the Lagrangian multiplier.

The Kuhn–Tucker conditions yield the following as shown in Equations (9) and (10):

$$\lambda = P\cdot\frac{\mathrm{d}F}{\mathrm{d}W} - \frac{\mathrm{d}C}{\mathrm{d}W} \tag{9}$$

$$W = \bar{W} \tag{10}$$

The Lagrangian multiplier in Equation (8) is the shadow value of water. It denotes the extent to which the surplus can be enhanced, if the constraint on water availability is released by a unit. As shown in Equation (9), at the equilibrium, this is given by the difference between the value of marginal product of water ($P.F_W$) and the marginal cost of water usage (C_w). This is what has been defined as the "scarcity value" of water.

Incorporating identity (1) into (8), the Lagrangian multiplier emerges as:

$$L(A,\lambda) = P.F(\omega.A) - C(\omega.A) + \lambda.(\bar{W} - \omega.A) \tag{11}$$

Differentiating Equation (11) with respect to and setting the same equal to zero yields:

$$\lambda = P\cdot\frac{\partial F}{\partial A} - \frac{\partial C}{\partial A} \tag{12}$$

The identical nature of the results obtained in Equations (9) and (12) suggest that in water scarce economies, the cultivated area can act as a proxy for the water variable. The same is exhibited in Figure 1. For simplicity, the price component *(P)* has been assumed to be unity here and thus the marginal product and the value of the marginal product are identical. Otherwise, it can also be assumed that the marginal cost is not expressed in monetary terms, but in terms of the crops. As has been derived under conditions of perfect competition, profit-maximising producers would produce until the point where the value of the last unit produced (marginal product) is equal to the cost incurred for the last produced unit (marginal cost).

However, for scarce resources, such a situation does not exist, owing to the constraints of availability. The diagram has also been extended to area in hectares to explain the phenomenon in 1B of Figure 1, where the area variable, *A*, replaces water, *W*. In 1A of Figure 1, it is assumed that

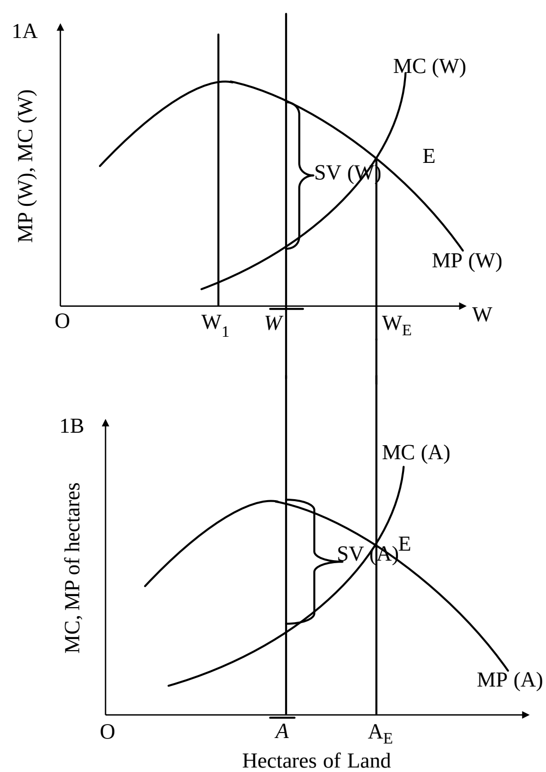

Fig. 1. Scarcity value of water reflected through loss in hectares of area.

production is taking place with a scarce resource like water. Like any other input in a well-behaved production function, it is assumed that the value of the marginal product of water is positive initially, increasing and then diminishing, while the marginal cost function is increasing (although it might show diminishing patterns in the initial values of water use). The former is given by MP_W, while the latter is given by MC_W in 1A. Under conditions of producers' equilibrium, the producer produces up to point E, where MP_W intersects MC_W. The water usage until that point results in the equilibrium water usage and is given by W_E in Figure 1.

Owing to the scarcity of the resource under consideration, the maximum availability of water is given by the vertical line emanating from $\bar{W}$, which denotes the resource constraint. This amount is less than the equilibrium quantity and the scarcity value originates from this point. The difference between the MP_W line and the MC_W line is the reflection of the extra value that could have been obtained had there been a small increase in water availability. However, this increase is not possible owing to the physical resource scarcity. In a simplistic framework, this difference between the value of marginal product and marginal cost is defined as the scarcity value of water at that point of time. The possibility of scarcity values increasing with water use may also happen in cases of extremely low physical availability of water.

As shown in Figure 1, part 1A, if the constraint had been fixed at a point of water use below W_1, the possibility of increasing scarcity values would have remained. It is presumed that such situations are usually very rare. Hence, if SV(W) denotes the scarcity value as a function of water use W, MP(W) denotes the marginal product of water W and MC(W) denotes the marginal cost of water W. The empirical estimation of scarcity values for the upstream and the downstream economies considering agricultural production will be based on the following definition:

$$S(W) = \mathrm{MP}(W) - \mathrm{MC}(W) \tag{13}$$

$$\frac{\partial(\mathrm{SV})}{\partial W} \geq 0, \quad \text{when} \quad W \leq W_1; \quad \text{and}$$

$$\frac{\partial(\mathrm{SV})}{\partial W} < 0, \quad \text{otherwise.}$$

Correspondingly, in 1B of Figure 1, it is shown that the constraint on water resources also constrains land use for that period, for the crop under consideration. The maximum available water, $\bar{W}$, allows the use of $\bar{A}$ hectares of land as shown in 1B of Figure 1. Under conditions of water scarce economies, there always remains a demand for higher water quantity and more hectares of land under the production function. While, the former constraint leads to the latter ceiling, the scarcity values indicated by both are in identical terms, although with varying units.

A simple numerical example can clarify things further. It is assumed that one hectare of crop X requires 16 units of water. In other words, $\omega = 16$ and let $\bar{W} = 256$. Hence, with the available water, the maximum possible area that can be brought under production, $\bar{A} = 16$. Inclusion of the 17th hectare of land implies the need for 16 more units of water. In other words, an extra unit availability of water implies that one-sixteenth of a hectare of land can be included under production, thereby resulting in an increase in the production. Hence, with simple conversion factors of multiples or sub-multiples scarcity value of water can be obtained from the scarcity value of land. The constraint defined by area thus perfectly reflects the scarcity value of water. For water scarce economies, land under production is a convenient and reasonable proxy for water use.

2.3 Methodology for empirically expounding the hypothesis

In a nutshell, the methodology for calculating scarcity value involves measuring the marginal product and the marginal cost and obtaining their difference. To obtain marginal product, we have assumed a log-linear Cobb–Douglas production function, with the natural logarithm of production as the dependent variable and area as the explanatory. The marginal product of area in a *C–D* function is simply the product of the slope coefficient and the average product. In the case of unavailability of data on water use, the same has been estimated from the area by multiplying the crop-water requirement by the total area (gross sown area). In the same manner, total water use has also been estimated. In this context, it should be understood that agricultural water demand is met not only by irrigation, but also by natural sources like rainfall, atmospheric moisture, soil moisture, and so on. In order to understand the actual water scarcity condition of the basin, all these sources need to be considered and not simply the sources of irrigation.

3. "Scarcity value induces disputes": an application in the Cauvery Basin in India

The Cauvery, about 800 km in length, is one of the major rivers of Peninsular India flowing eastwards from Talakaveri at 1341 masl in the Western Ghats uplands into the Bay of Bengal. The basin area of the river is 87,900 km^2. It is an inter-state river according to the provisions of the Indian Constitution with Karnataka and Tamil Nadu as the major states staking their claim to the Cauvery water. The other states sharing the basin are Kerala and Pondicherry, which benefit in a minor way from its waters. The basin is divided physiographically in three parts; the Western Ghats uplands, the Plateau of Mysore and the Delta (MOWR, 1989). An extensive irrigation network was developed by the British rulers in the delta region now belonging to the state of Tamil Nadu. Karnataka has started to expand irrigated agriculture only in the last few decades. Around 89% of the total water withdrawal in the basin is for agriculture (Amarasinghe, 2003:12). As argued by Ghosh (2005) and also exhibited in Guhan (1993), the Cauvery basin is a water scarce economy, where an increase in crop acreage took place with developments in irrigation potential over time.

3.1 History of hostile hydropolitics and the institutional response

The existing controversy over the waters of the Cauvery should be seen as a continuation of the historical process that was initiated long ago. The origin of the accentuation of the present problem between the two states of Karnataka and Tamil Nadu can be taken as at the conclusion of the era of the 1924 agreement in 1974. By this time, the states of Kerala and Pondicherry, which were not parties to the 1924 agreement, had also become involved in the present controversy (Iyer, 2003), as minor stakeholders. However, the states of Karnataka and Tamil Nadu, being the major users of the Cauvery waters, were the main parties in the debate.

Despite two decades of intermittent talks between the two states, no solution was reached. There were also attempts by the Government of India (henceforth GoI) to bring about an agreement, but they remained "attempts only" without producing any concrete result.

Thereafter, despite repeated efforts by the central government to settle the dispute and discussions at the level of the chief ministers of the concerned states, the dispute remained unresolved. The government of Tamil Nadu made a formal request to the government of India in July 1986 under the provisions of

Inter-State Water Disputes Act, 1956 for the constitution of a tribunal. The central government did not set up the tribunal immediately, perhaps, with the vision that adjudication is not the best means for settling such disputes and a better course of action would be mutual agreement through negotiations. Dissatisfaction was expressed by the Tamil media with the central government regarding the issue (Nalankilli, 1998a, b). There was this feeling among one section that GoI were indifferent to the woes of the Tamil farmers.

At this juncture, a long-pending petition by some Tamil Nadu farmers was presented to the Supreme Court, for an assurance of irrigation water from the Cauvery. After the hearing, the Supreme Court, taking note of the failed negotiations and the fact that a request from Tamil Nadu to set up a tribunal was pending, ordered the central government to establish a tribunal within a month. The Cauvery Water Disputes Tribunal was set up in accordance with Section 4 of the Inter State Water Disputes Act, 1956, on 2 June 1990 with its headquarters at New Delhi (Iyer, 2003).

The intervening period, however, has not been free from conflict. Controversy was ignited by an Interim Order (IO) of 1991 that was passed by the tribunal, for water sharing until the final award comes to force. There was a plea from Tamil Nadu that pending the adjudication process there was need for assurance of irrigation water. According to the IO passed by the tribunal, Karnataka was supposed to release 205 TMC (thousand million cubic feet; 6.15 thousand million m^3) of Cauvery waters to Tamil Nadu annually (of which 6 TMC or 180 million m^3 should go to Pondicherry) and was also to lay down a detailed monthly schedule of releases (Iyer, 2003). The figure of 205 TMC (6.15 thousand m^3) was arrived at by taking the average of the flows for 10 years from 1980/81 onwards, eliminating the abnormally good and the bad years.

While Tamil Nadu wanted the central government immediately to notify the ordinance and warrant its implementation, Karnataka was of the view that the order was unfair and cannot be implemented, as it would hurt the interests of its farmers. This forced the central government to make a reference to the Supreme Court for its opinion. The apex court gave its opinion in favour of the notification of the Internal Order (IO). Karnataka continued to feel that it was not possible to implement the order was and made a reference back to the tribunal, which reaffirmed its order, observing that situations of abnormally low flows could be dealt with when they arose and that a *pro rata* adjustment could be made (Iyer, 2003). However, owing to the fact that the tribunal did not lay down any detailed formula for such contingencies, in the following decade problems ensued on various counts from the IO and in relation to flow from the Cauvery during the seasons when water flow/rainfall was scarce/reduced. For the three successive years, there were good rains. Tamil Nadu was anxious that the binding nature of the IO should be recognised, until the final award come to force (Iyer, 2003).

The problem was initiated during 1995/96 when rainfall was inadequate. Tamil Nadu went to the Supreme Court asking for an immediate release of 30 TMC (899 million m^3) by Karnataka (calculated with reference to claimed shortfalls in releases) to save the standing crops in Thanjavur. Tamil Nadu was asked to approach the tribunal with its request. The tribunal listened to the woes of both parties and ordered the release of 11 TMC (330 million m^3) to the Mettur Dam with immediate effect. Karnataka did not show any intention of upholding the order and the matter was taken to the Supreme Court. The apex court requested the Prime Minister to intervene and with the intervention of the latter, Karnataka released 6 TMC (180 million m^3) of water (Menon & Subramanian, 2002; Iyer, 2003).

On the other hand, apprehension concerning the implementation of the IO of 1991 continued. The Cauvery River Authority (CRA) was set up in 1998 to oversee the materialisation of the IO. It consisted of the Prime Minister at its the head and the Chief Ministers of the four states as members. This was conceived of essentially as the machinery augmenting the process of dispute resolution. However, it has not been of much significance so far (Venkatesan, 1998). The attempts made by CRA at resolution so far have been myopic, showing no semblance of a sustainable solution, and have been criticised as, at most, postponing the crisis (Menon & Subramanian, 2002).

The Tamil Nadu government filed cases relating to Cauvery water in 1992, 1995, 1997 and 2001, hoping for a directive to Karnataka to implement the IO of the tribunal so that the standing *kuruvai* crop in Tamil Nadu could be saved. The *kuruvai* crop is dependent on irrigation from the Mettur Dam, which in turn receives water from upstream reservoirs in Karnataka (Menon & Subramanian, 2002). The *kuruvai* crop is the rice sown during the months of April to July and its growth period coincides with the south-west monsoon, that is, from June to September.

The controversy arose in 2002, when the rains were exceptionally bad. The monsoons not only failed to arrive in time, but when they arrived, they were woefully inadequate. Tamil Nadu approached the Supreme Court, which, in an order on September 3, 2002, directed Karnataka to release 1.25 TMC (37.5 million m^3) of water to Mettur betweem September and November (Janakarajan, 2003). In 2004, this controversy emerged again, but was resolved by the arrival of the monsoons.

The tribunal declared a final award after a long wait of almost 17 years on February 5, 2007. The tribunal determined that the total utilisable waters from the Cauvery was 740 TMC (20,954 million m^3), for the states on the basis of 50% dependability. During the process, it allotted 419 TMC (12.57 million m^3) (compared with its demand for 562 TMC (16.86 million m^3)) of Cauvery river water to Tamil Nadu; 270 TMC (8.1 million m^3) (compared with its demand for 465 TMC (13.95 million m^3)) to Karnataka; 30 TMC (899 million m^3) to Kerala and 7 TMC (210 million m^3) to Pondicherry. While 726 TMC (or 21.78 million m^3) of water, the tribunal "reserved" 14 TMC (420 million m^3) for "environmental protection" (10 TMC or 30 million m^3) and "inevitable escapages to the sea" (Anon, 2007). These provide hardly any realistic estimates of EFRs (environmental flow requirements). Between the two major stakeholders, Karnataka and Tamil Nadu, the allocation has been far from satisfactory. Karnataka has been ordered to release 192 TMC or 5.76 million m^3 of water (which is 12 TMC or 360 million m^3 more than was specified in the IO) at the inter-state contact point presently identified as the Billigundulu gauge. The basis of allocation has been vague, whether in terms of ecological principles or on the basis of economic logic. Karnataka has already expressed its discontent to the press, stating that the state would file a petition seeking review of the tribunal's final order.

Property rights over water resources are classified as historical rights (defined in terms of who extracted water first), Hobbesian rights (rights defined in terms of negotiations) and on the basis of Harmon doctrine (rights defined in terms of "if water falls on my roof, it is mine"). In the context of the Cauvery waters, upstream Karnataka defines property rights in terms of the Harmon doctrine, while downstream Tamil Nadu defines rights over water in terms of the history doctrine. There has been extensive "Hobbesian" behaviour in the basin over water, which has resulted in hostile discussions/action by both parties. The notion of *hostile hydropolitics* in the Cauvery Basin has arisen.

3.2 The approach to the present analysis

To conduct the present study, districts have been selected from Karnataka and Tamil Nadu on the basis of the availability of data and also on the feasibility of data compilation. This is due to the problems caused by redefinition of quite a few districts in both states. The data involve current time-series data on seven of the 10 districts of Karnataka in the Cauvery Basin and 11 districts of the 15 existing districts of Tamil Nadu in the Cauvery Basin. Paddy happens to be the crop with the maximum acreage in the basin region covering the states of Karnataka and Tamil Nadu. The acreages of the major crops is given in Table 1.

Evidently, the dispute between the two states has centred around water availability for paddy. Hence, this analysis has attempted to explain the disputes over the waters of the Cauvery in terms of the scarcity value of water in the region with respect to the production of paddy. Considering an average water use at 175 cm for paddy, the marginal product of water and total water use has been estimated. Total water use is simply the product of area and crop water requirement, which in the case of paddy is 175 cm (Lourduraj & Bayan, 1999; Chattopadhyay *et al.*, 2000; Boumann & Tuong, 2001). The marginal product of gross sown area has been estimated from the average product of gross sown area, which emerges easily from a Cobb–Douglas production function. The marginal product of water per unit has been obtained by dividing the marginal product of area by 175 cm of water use, with the assumption that unit area under rice requires 175 cm of water. The marginal costs of water have been obtained by deflating the water rates with respect to the minimum support price of the crop announced by the Government of India for the particular year being examined. The Directorates of Economics and Statistics of the respective state governments have provided the production and area data, while the source of data on agricultural water rates is *Pricing of Water in Public System in India* (published by the information systems organisation, Water Planning and Projects Wing of the Central Water Commission, New Delhi). Data on the minimum support prices comes from *Agricultural Statistics at a Glance 2001* and earlier volumes published by Ministry of Agriculture, Government of India.

3.3 Scarcity value of water in the Cauvery Basin in Karnataka with respect to paddy

Karnataka has three paddy growing seasons in the Cauvery Basin: *kharif* (August to November), *rabbi* (December to March) and *summer* (April to July). Estimates of the scarcity value of water along with total water use for the region are given in Table 2. It shows that paddy is most extensively a *kharif* crop, with the maximum water use. This is followed by the *summer* and *rabbi* crops, respectively. In order to draw a comparison between the scarcity values in the 1980s and the 1990s and water uses, it is necessary to consider them seasonally. The results for each season are given in Table 2.

Kharif: the use of water has been below $5 \times (10^9)$ cubic metres (BCM) in all the years of the 1980s. There were five years in the 1980s when water use had been 4.5 BCM. It even dipped to less than 4 BCM in 1987/88. Only in 88/89, did it slightly exceed 5 BCM. In the 1990s, there were five years where this water use was been higher than 5 BCM. Again, the F-statistic for testing the equality of the variances for the two periods suggests that the there was no change in terms of the fluctuations of water use in the 1990s, compared to that in the

Table 1. Acreages of major crops in 1991/92 and 1997/98 in the study area of the Cauvery Basin.

Crop		Rice	Jowar	Bajra	Maize	Ragi	Sugarcane
Area (in hectares)	1991/92	1,136,908	3,948,35	77,867	51,510	664,151	181,105
	1997/98	1,254,082	294,698	32,453	67,460	624,288	178,073

Source: Compiled by the authors from: Indian Agricultural Statistics 1991/92, Ministry of Agriculture, Govt. of India. Official Website of Drought Monitoring Cell, Govt. of Karnataka (dmc.kar.nic.in). *Season and Crop Report 1991/92*, Department of Economics and Statistics, Government of Tamil Nadu. *Karnataka at a Glance 1998/99*, Directorate of Economics & Statistics, Government of Karnataka. *Season and Crop Report 1997/98*, Department of Economics and Statistics, Govt. of Tamil Nadu.

Table 2. Scarcity value of water and average water use for rice in the Cauvery Basin districts in Karnataka (1980/81 to 2000/01).

Year	Kharif rice		Rabbi rice		Summer rice	
	Average scarcity value (kg m^{-3})	Average water use (million m^3)	Average scarcity value (kg m^{-3})	Average water use (million m^3)	Average scarcity value (kg m^{-3})	Average water use (million m^3)
1980/81 to 1985/86	0.2242	4,581.2171	0.2068	11.1708	0.1664	584.3104
1986/87 to 1990/91	0.1993	4,463.1020	0.2095	107.3835	0.1767	808.8115
1991/92 to 1995/96	0.1755	4,909.5410	0.1553	118.8880	0.1820	1151.9935
1995/96 to 2000/01	0.1994	5,431.4619	0.1477	123.4188	0.1723	1240.6844

Source: estimated by the authors.

1980s. As far as scarcity value is concerned, in the 1980s, it dropped below 0.2 kg per hectare only for 1987/88, but that too hovered above 0.197 kg per hectare. But in the 1990s, it was always lower than 0.2 kg per hectare. 2000/01 also provided an exception. In terms of fluctuations, there was no significant change in the 1990s, compared to the 1980s. When a t-test was conducted for the change in the means of the scarcity values in the 1990s, compared to those in the 1980s, the following was observed: the 1990s witnessed a significant decline in the mean scarcity value, associated with a significant increase in total water use, as compared to those in the 1980s, for *kharif* rice.

Rabbi: between the two periods, the mean area under paddy increased by more than 150%. The 1980s witnessed a huge fluctuation in the scarcity values, which more or less stabilised in the 1990s. During the initial phases of the 1980s, scarcity values were low and from 1983/84 onwards there was a significant increase. The 1990s saw the fall in the scarcity values and the fluctuations also diminished. This is evident from a significant decrease in the standard deviation of the scarcity value in the 1990s, compared to the 1980s. In 2000/01, there was a sharp increase in the scarcity value. The t-test revealed that: the 1990s witnessed a significant decline in the mean scarcity value of water together with a significant increase in the total use, as compared to the 1980s.

Summer: throughout the two decades, the scarcity value of water with respect to *summer* paddy has remained in the range 0.15–0.2 kg per hectare. The 1990s clearly reflect a significant leap in water use. For most of the years in the 1980s, total water use in the districts considered in the analysis remained between 0.5 and 1 BCM (with the exceptions of 1982/83, when it was below 0.5 BCM and 1988/89, when the water use went above 1.2 BCM). For most of years of the 1990s water use was between 1 and 1.5 BCM. In 1991/92, it went beyond 1.7 BCM, while it fell to around 0.6 BCM in 1995/96. The t-statistic revealed the following: the 1990s witnessed a significant increase in the total water use, associated with no significant decline in the scarcity values, as compared to the 1980s, for *summer* rice.

3.4 Scarcity value of water and its use for paddy in the Cauvery Basin in Tamil Nadu

There are three agricultural seasons of paddy in Tamil Nadu, as given in the various volumes of *Season and Crop Report* of the Department of Economics and Statistics, Government of Tamil Nadu.

From 1980/81 to 1986/87, they have been reported as Paddy 1, Paddy 2 and Paddy 3. Their estimates are given in Table 3.

Interestingly for the subsequent years, data have been presented by the names of Samba/Thaladi/Pishnam (August to November), Navarai/Kodai (December to March) and Kar/Kuruvai/Sornavari (April to July). In terms of cropping, the *kuruvai* coincides with the south-west monsoon season, Samba coincides with the north-east monsoon season, while Navarai coincides with the hot summer months. For the period from 1987/88 to 2000/01, estimates have been presented in Table 4.

Table 4 clearly goes on to show that the highest scarcity values have been occurring for *kuruvai* paddy. During the late 1980s, the scarcity value of water was extremely high, at 0.28 kg of rice per cubic metre of water. This was also a phase when water use for *kuruvai* was least. There are always attempts in parts of the states to diminish the scarcity value of water by bringing in more water to the system. Eventually, the 1990s witnessed a massive increase in water use through supply augmentation plans and this was also a phase when Karnataka was compelled to release a certain quantity of water for the given phase of *kuruvai* paddy. This led to a massive increase in acreage under *kuruvai* and enhanced its importance in the total rice production in the state. It can be seen that water use for *kuruvai* paddy has increased by almost 250% and the increase is statistically significant according to the t-statistic. However, the decline in the scarcity value is not statistically significant. According to the t-test of the equality of the means, the other two seasons, however, have revealed neither any change in scarcity value, nor in the annual average water use.

3.5 The Cauvery disputes and scarcity values: a superimposition

The Cauvery water has become a matter of more intense political dispute ever since the non-renewal of the 50-year-old agreement between the Madras Presidency (later on, Tamil Nadu) and the Princely State of Mysore (Karnataka) in 1974. Political parties in the two states are ready to champion the cause of respective farmer groups, where their constituency votes (vote bank) rest. Unfortunately, the dialogues that have taken place so far have been confined to the political ambit and, as a result, have only hardened positions further in both states. The situation came close to developing into a constitutional crisis in 2002, when Karnataka declined to agree to the Supreme Court order to release 0.8 TMC of water for downstream Tamil Nadu. Strong words from the apex Court to Karnataka made it comply and the

Table 3. Scarcity value of water and water use for rice in the selected Cauvery Basin districts in Tamil Nadu (1980/81 to 1986/87).

	Paddy 1		Paddy 2		Paddy 3	
Year	Scarcity value (kg m^{-3})	Total water use (in 10^9 m^3)	Scarcity value (kg m^{-3})	Total water use (in 10^9 m^3)	Scarcity value (kg m^{-3})	Total water use (in 10^9 m^3)
1980/81	0.131689	12.932763	0.134689	3.581043	0.173575	0.026128
1981/82	0.191082	13.866265	0.134299	3.740555	0.203525	0.048055
1982/83	0.142773	12.210590	0.112168	2.421493	0.176411	0.032988
1983/84	0.150136	13.311130	0.106121	1.998588	0.194119	0.042228
1984/85	0.188086	13.056418	0.126354	4.054488	0.197816	0.034528
1985/86	0.208059	11.800863	0.137244	2.161163	0.171466	0.083283
1986/87	0.212553	12.153050	0.180441	1.037523	0.240103	0.110548

Source: estimates by authors.

Table 4. Scarcity value of water and water use for rice in the selected Cauvery Basin districts in Tamil Nadu (1987/88 to 2000/01).

		Samba/Thaladi/Pishnam		Navarai/Kodai		Kar/Kuruvai/Sornavari	
Phase	Year	Scarcity value (kg m^{-3})	Average annual water use (in 10^9 m^3)	Scarcity value (kg m^3)	Average annual water use (in 10^9 m^3)	Scarcity value (kg m^{-3})	Average annual water use (in 10^9 m^3)
Late 1980s	1987/88 to 89/90	0.20889	11.49742	0.20746	0.57621	0.28021	0.65124
Early 1990s	1990/91 to 93/94	0.17163	11.25177	0.18930	0.96355	0.21309	1.57011
Mid-1990s	1994/95 to 96/97	0.14870	11.75764	0.19992	0.57099	0.21451	1.82149
Late 1990s to new millennium	1997/98 to 2000/01	0.17633	15.05974	0.22003	0.75109	0.22735	2.20993

Source: estimates by authors

situation was saved. The recent turn of events has gone on to show that the dispute between Tamil Nadu and Karnataka could shake the foundation of India's federal structure of governance and polity, despite the interventions of the Government of India and the highest judicial authority of the country.

A prudent analysis of the longstanding and a widely debated dispute between Karnataka and Tamil Nadu exposes the sense of distrust that they show for each other. Following Janakarajan (2003), the dispute diagram presented below gives a historical view of the intensity of the dispute.

The problem has been intensifying over time and the situation in the Cauvery basin is nothing short of a crisis. Before 1924 and during the agreement period between 1924 and 1974, there were sporadic protests. This is stage 1 in Figure 2, denoted by a few black dots but by and large the basin area has not been very trouble prone. In stage 2, that is, between 1974 and 1990, the dispute has intensified and distrust has been built up between the two states. As has often been alluded to in the literature, one of the major reasons for this is lack of non-partisan information dissemination and lack of communication among the stakeholders (Iyer, 2003; Janakarajan, 2003). This is denoted by extensive black dots.

The period subsequent to 1990 is witness to stage 3 of the diagram, where crisis sets in, with black dots dominating over the white dots. This is the stage where the dispute is presently seated and the last stage where some initiative can still save the situation. Lack of any initiative at this phase will land the dispute at stage 4, which will be catastrophic not only for the farmers of the Cauvery basin but also for the entire region. This stage, denoted by complete darkness in the diagram, would be irretrievable.

At the same time, it should also be noted that disputes have been occurring primarily because of the requirements of the *kuruvai* crop in Tamil Nadu. It should be noted that throughout the period, the crop with the highest scarcity value of the three is the *kuruvai* crop. It has already been pointed out that in Tamil Nadu, the *kuruvai* crop has been assuming so much importance that water use has increased substantially for this season, without any significant decline in its scarcity value. This is actually the prime mover of the dispute making a very difficult situation, as far as water use is concerned. A non-declining scarcity value implies that the excess water demand component (demand-supply) has not been responding to the increases in supply. In other words, with more water moving into the field, the requirement has also grown.

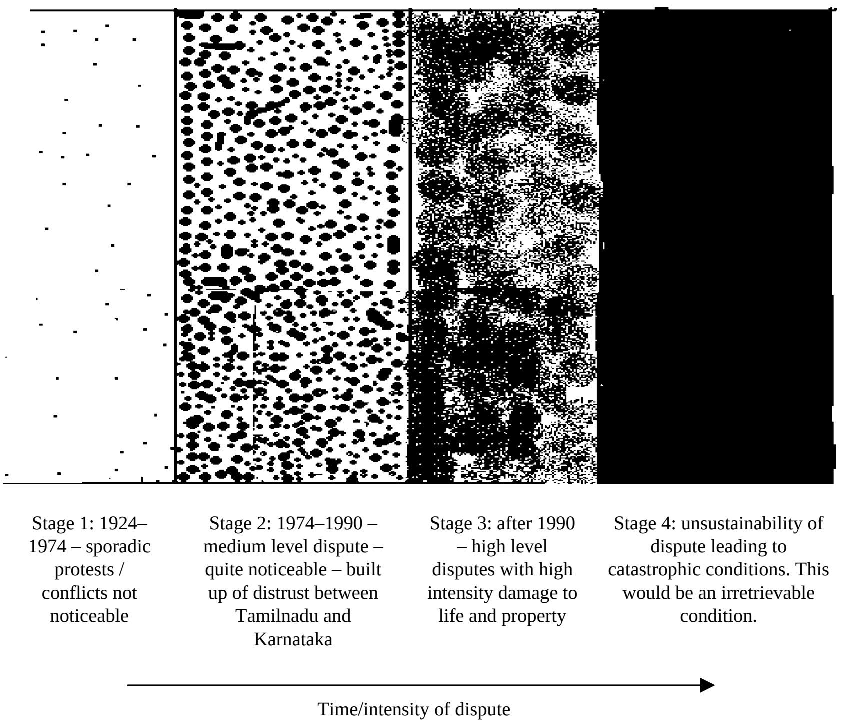

Fig. 2. Degrees of conflicts and sustainable development in the Cauvery Basin. *Source*: based on Janakarajan (2003).

With rice gaining significant importance as the main staple in Karnataka, farmers in the state, like in Tamil Nadu, are also keenly interested in reducing the scarcity value of water in paddy cultivation. With significant increases in water use associated with significant decline in the scarcity values, there has rarely been a problem arising for its *kharif* and *rabbi* paddy crops. Its problem is again with the *summer* paddy crop. The mean water use increased significantly for the *summer* crop in the 1990s, without any associated decline in its scarcity value. This situation is identical to that witnessed in Tamil Nadu for *kuruvai*.

According to the Directorate of Economics and Statistics of Tamil Nadu, the sowing period of the *kuruvai* paddy is from April to July, which almost coincides with the growth period of *summer* rice in Karnataka. The demand for water for the *kuruvai* paddy in Tamil Nadu starts to grow just after Karnataka has used water for the *summer* rice or at the time of its late growth period. As noted from the scarcity value dynamics for the respective seasons, in both the states in the basin, there is a demand of water for rice, which has not been reduced by increases in water use for rice. Guhan (1993) aptly puts the Cauvery water dispute as concerning the issue not of sharing but of re-sharing the river water. The question of re-sharing appears as the Cauvery water has already been optimally allocated. This re-sharing becomes extremely vital for the rice of the *summer* and the *kuruvai*. Owing to the compulsions of vote bank politics, none of the states are willing to sacrifice any part of the available water. The situation has been pushed to an impasse, thereby reconfirming the existence of “zero-sum” equilibrium. If the status quo persists, the situation will move towards the irretrievable darkness, as propounded in Figure 2.

Preparing a dispute chronology from various sources like Iyer (2002 and 2003), Guhan (1993), Menon & Subramanian (2002) and Janakarajan (2003), Table 5 attempts to provide a more specific link-up.

Table 5. Years of significant occurrences and the associated scarcity values in the 1980s and 1990s.

Year	Characterisation of scarcity value and water use for rice	Occurrence in the specific year
Early and mid-1980s (1980/81 to 1986/87)	Highest annual scarcity value and lowest annual water use for rice in this period in Tamil Nadu was observed in 1986/87.	Tamil Nadu makes a formal request to the Government of India in July, 1986 under the provisions of Inter-State Water Disputes Act, 1956 for constitution of a tribunal.
Late 1980s (1987/88 to 1989/90)	Tamil Nadu witnesses the highest scarcity value of the decade in 1988/89. This was high for all the three crops and highest for Kuruvai. A very high scarcity value was also observed in Karnataka in 1989/90.	Internal problems in the state; farmers ask for more water. Water slowly emerging as the prime political concern. Supreme Court Order to set up tribunal.
Early 1990s (1990/91 to 1993/94)	A phase of transition with annual scarcity values lower than the preceding period for Tamil Nadu. In Karnataka, the scarcity value for the Summer crop increased substantially in 1991/92, compared to the previous decade. A high scarcity value was observed in Tamil Nadu in 1991/92, with kuruvai having the most dominant effect.	Cauvery Water Tribunal wasset up in 1990. Passing of interim order by water tribunal leading to unrests in Karnataka, against the residing Tamils. Thousands of Tamils and their properties were the target of attack in Karnataka in 1991. Tamil Nadu Moved to Court in 1992, after the occurrence of the high scarcity value in agriculture in 1991/92.
Mid-1990s (1994/95 to 1996/97)	Kuruvai crop in 1994/95 and 1996/97 witness to high scarcity values of water in Tamil Nadu. In Tamil Nadu, Water use was extremely low in 1995/96 and 1996/97. 1994/95 and 1995/96 are the years where the Summer crop in Karnataka witnessed high scarcity values. 1995/96 witnessed the minimum water use for summer rice for both the states.	Tamil Nadu went to Court in 1995. This was also a year of inadequate rainfall.
Late 1990s to the new Millennium (1997/98 to 2000/01)	A phase witnessing increasing scarcity values with increasing water use over the phase of the four years for Tamil Nadu. The crop with the highest scarcity value was Kuruvai. For Karnataka, there was no substantial change in the scarcity value between 1998/99 and 2000/01.	Tamil Nadu moving to court in 1997 and again in 2001, following years of three consecutive high scarcity values.

3.6 Rainfall, flows to the Mettur Dam, scarcity values and conflicts

If analysed properly, what can be observed in the disputes over the Cauvery Waters is that the controversy has erupted primarily during June, the month when the *kuruvai* rice in Tamil Nadu starts to make a demand on water. However, this clashes with the *summer* rice of Karnataka, whose cropping season continues until July. There are two major sources from which water can be obtained for production in the Cauvery Basin region – rainfall and the Cauvery. While we have established that a non-diminishing scarcity value, associated with a significant increase in area under the two rice crops in the 1990s, compared to the 1980s, has resulted in the intensification of disputes, we assess the condition of water flow, use and rainfall in the 1990s (Table 6).

The late 1990s, starting from 1997/98, witnessed a huge decrease in June rainfall in Tamil Nadu and as the negative sign suggests, it has been substantially lower than the normal. A non-diminishing scarcity value, associated with an extensive increase in the area under rice, created a situation of a high "unmet" demand for water. Hence, the pressure was on the other prime source of water, that is, the waters of the Cauvery. In addition, as observed, for a large part of the 1990s, the flow to the Mettur Dam in Tamil Nadu was lower than the prescribed flow. This is, quite evidently, due to the fact that while upstream Karnataka's water use has increased, there has been no significant decline in their scarcity values.

4. Analysis of a few causes and the options

4.1 The causes

The analysis highlights the fact that it is principally the simultaneous water requirement of the *summer* paddy in Karnataka and the *kuruvai* paddy in Tamil Nadu that is at the root of disputes over the Cauvery waters. The constantly growing water requirements of the very dominant *summer* paddy crop in Karnataka and an even more dominant *kuruvai* paddy crop in Tamil Nadu cannot be satisfied. If not addressed, the situation will finally lead to one of outright conflict, one depicted by complete darkness in stage 4 of Figure 2. The non-diminishing scarcity values together with increasing water use for the aforementioned crops of rice in the region, indicate that disputes will surely grow. Supply augmentation plans are bound to fail under this situation, where water is subject to non-satiation – "unmet" demand for water is non-responsive to water supply. This problem prevails because of the dominating position of rice, in terms of acreage. Data by *Directorate of Economics and Statistics* suggest that for most of the other crops, there has hardly been any increase in acreage.

Ragi (finger millet) earlier used to be a major staple food in the region, particularly in Karnataka. For centuries, ragi was synonymous with health for people in the southern parts of the state. The acreage under ragi or other staple crops has not increased, despite increases in irrigation potential. Hence, benefits from the major irrigation projects have primarily gone to paddy. The significant increase in water use to produce paddy during the three seasons is occurring because of a number of factors.

The first factor involves changes in consumption patterns induced by government policies. The movement of production can be attributed to the movement of prices. If a minimum support price is considered as one such price, its movement clearly explains this consumption shift. The price differential between rice and ragi is not statistically significant. However, when one considers the relative prices (price of ragi divided by that of rice), the mean price ratio in the 1990s increased significantly, compared

Table 6. Rainfall, flows to the Mettur, water uses and scarcity values.

Year	Percentage deviation from normal rainfall in Karnataka during June*	Percentage deviation from normal rainfall in Tamil Nadu during June†	Percentage deviation from the prescribed flows to the Mettur in June‡	Annual average scarcity value for Kar/Kuruvai/Sornavari (kg m^{-3}) in Tamil Nadu	Water use for Kar/Kuruvai/Sornavari in Tamil Nadu (in million m^3)	Scarcity value for Summer (kg m^{-3}) in Karnataka	Water use for Summer crop in Karnataka (in million m^3)
1991/92	96.52	85.31		0.213 31	1.061 50	0.174 6785	1.728 545
1992/93	157.76	38.01	35.58	0.199 92	2.299 99	0.178 4168	1.024 135
1993/94	44.26	42.34	−52.71	0.227 21	2.206 80	0.181 786	1.310 8025
1994/95	67.96		−52.63	0.219 69	2.590 18	0.191 5447	1.071 84
1995/96	−6.67	8.71	−58.01	0.201 15	1.533 51	0.191 8661	0.624 645
1996/97	116.54	108.68	−51.79	0.219 77	1.340 80	0.175 2146	1.116 255
1997/98	55.16	−27.78	−71.94	0.213 70	2.030 82		
1998/99	53.68	−39.29	−84.69	0.231 26	2.171 82	0.181 3486	1.319 3425
1999/00	−0.53	−53.37	2.63	0.230 29	2.130 50	0.165 7302	1.072 575
2000/01	53.98	−55.87		0.232 53	2.506 56	0.166 8681	1.454 565
2001/02	24.54	−45.70					

Source: estimated by author from:
* dmc.kar.nic.in
† *Season and Crop Report*, Department of Economics and Statistics, Government of Tamil Nadu, Chennai.
‡ Menon & Subramanian (2002).

to those of the 1980s. Hence, the relative incentive to produce paddy is higher on the part of the producer, compared to ragi. This is presented in Table 7.

The public distribution system has further promoted sale of rice at a much lower price than other staple crops. The other point is that the real cost of irrigation waters is diminishing. There were attempts in the late 1980s to revise the very low irrigation water access rates significantly, but it was not possible because of protests from farmers. Therefore, the real cost of irrigation, in the present day context, has become inconsequential, to the extent of making agricultural waters in the basin almost free. This prevents more efficient demand side management of water.

A question might also arise as to why scarcity values are non-diminishing with water use for *summer* and *kuruvai* crops in the respective states. This “non-diminutive” characteristic of scarcity value is attributed to the to the importance of technology and knowledge, although this explanation is not considered to fall in the ambit of this analysis. Note that the 1990s witnessed better agricultural practices, in terms of better use of fertilisers and greater technological interventions, which have not allowed the marginal products to diminish. Particularly, the yield rate per hectare did not diminish in the 1990s, for the *summer* and *kuruvai* paddies.

Despite the fact that increased water use should have brought down scarcity values, there are dominant counteractive forces, to step up the yield. These occur in the form of higher fertiliser use per hectare, greater input density per hectare, and so on. The counteractive forces probably reveal their maximum dominance during the *summer* paddy season and do not allow the scarcity values to diminish.

Table 7. Movement of the ratio of the minimum support prices (rice/ragi) 1980/81 to 2000/01.

Year	(Minimum support price of rice)/ (minimum support price of ragi)
80/81	1.00000
81/82	0.99140
82/83	1.03390
83/84	1.06450
84/85	1.05380
85/86	1.09230
86/87	1.10610
87/88	1.11110
88/89	1.10340
89/90	1.12120
90/91	1.13890
91/92	1.12200
92/93	1.12500
93/94	1.19230
94/95	1.21430
95/96	1.20000
96/97	1.22580
97/98	1.15280
98/99	1.12820
99/00	1.18070
00/01	1.14610

Source: computed by author from *Agricultural Statistics at a Glance 2001* & past issues, Ministry of Agriculture, Government of India.

With the higher inputs of fertilisers, the yield rates are increasing. Tables 8 and 9 show the prevalence of the counteracting forces, in terms of the district-level data for the two states of the Cauvery basin.

It should also be remembered that the introduction of the hybrid rice in Karnataka happened in the mid-1990s. Janaiah (2000) shows that farmers cultivating hybrid rice realised higher yield gains at 16% over current inbred varieties in the similar agro-climatic zones of the south Indian states of Andhra Pradesh and Karnataka. Chengappa *et al.* (2003) argue that hybrid rice, despite being high yielding, requires greater use of fertilisers and other inputs. Hence, in order to maintain the factor-proportion, the demand for water also increases, thereby increasing the latter's scarcity value. Hence, during the 1990s, there remained a high chance of the scarcity value of agricultural water becoming less sensitive to water use for important rice crops during the growing season for *kharif* and *summer*.

However, the non-diminishing marginal product of land or water might not be correct for very high levels of water use, like that for *kharif* paddy in Karnataka. However, existing counteractive forces have not allowed a reversal in the relationship (from "increasing" to "diminishing") between scarcity value and water use. Again, *rabbi* presumably is not a significant crop and associated input use can be presumed to have no significant effect in increasing the yield rates. Hence, in the 1990s, with an increase in rice demand, despite the increase in acreage and water use for *rabbi* rice, the counteractive forces were dominant enough, thereby resulting in a total reversal in the relationship.

In the context of Tamil Nadu, for Samba/Thaladi/Pishnam and Navarai/Kodai, the scarcity value situation in the 1990s, compared to the 1980s, can be explained, in terms of the neoclassical framework propounded in this analysis. The non-declining scarcity value with increased water use for *kuruvai* rice can be attributed to a non-diminishing marginal product. Ramasamy *et al.* (2003) have observed that the yield increase in paddy was largely due to widespread adoption of modern rice varieties in favourable irrigation environments. More than 90% of the sown area is under modern rice varieties. They also suggest that chemical fertiliser consumption has increased in the state. This is one of the major counteractive forces that have not allowed marginal products to diminish, despite increases in water use. Modern rice varieties, even those involving the hybrid seeds, require greater use of fertilisers, which also require greater water use, for the retention of the factor proportion. This increases the per unit demand for water at the margin. The combined figures for fertiliser consumption, estimated from the CMIE online database *Indian Harvest,* for the Cauvery basin districts of Tamil Nadu also reveal an increase

Table 8. A few indicators of counteractive forces in the form of fertilisers and pump sets.

Hassan	Year	1982	1999	Year	1982	2001
	Fertiliser use (kg ha^{-1})	51.23	123.48	Pumpsets/000 ha	11	83
Kodagu	Year	1982	1999	Year	1982	2001
	Fertiliser use (kg ha^{-1})	59.32	210.11	Pumpsets/000 ha	10	26
Kolar	Year	1982	1999	Year	1982	2001
	Fertiliser use (kg ha^{-1})	40.60	120.74	Pumpsets/000 ha	109	296
Mandya	Year	1982	1999	Year	1982	2001
	Fertiliser use (kg ha^{-1})	98.88	198.73	Pumpsets/000 ha	20	134
Mysore	Year	1981	1999	Year	1987	2001
	Fertiliser use (kg ha^{-1})	33.58	105.70	Pumpsets/000 ha	26	55
Tumkur	Year	1982	1999	Year	1982	2001
	Fertiliser use (kg ha^{-1})	23.38	62.90	Pumpsets/000 ha	52	188

Source: computed by the author from CMIE database *Indian Harvest*.

Table 9. Estimates of counteractive forces in the Cauvery Basin districts in Tamil Nadu.

Year	Fertilizer use (kg ha^{-1}of gross sown area)	Year	Number of tractors per hectare of gross sown area
Dec-82	78.87	Dec-91	0.04927
Dec-98	117.86	Dec-00	1.71733
Dec-01	210.34		

Source: computed by the author from CMIE database *Indian Harvest*.

from 79 kg ha^{-1} in December 1982 to 210 kg ha^{-1} in December 2001, as evidenced in Table 8. In order to enforce these contentions for both Karnataka and Tamil Nadu, there remains the need for farm-level studies which are not within the scope of the present paper.

4.2 The options

As has been mentioned, despite being a water-consuming crop, paddy has been given extensive importance in the basin, which is under "chronic water scarcity", according to the Falkenmark indicator. A non-diminishing scarcity value for rice in such a zone, where water has been used to its full potential, is unsustainable. The first option may be a crop diversification policy on the part of the governments of the two basins to shift the periods of demand and also to reduce the total demands altogether. Giving up a portion of the production of *summer* and *kuruvai* paddy, increasing ragi production and opting for virtual water imports for rice are apparent remedies. Government policy, thus, becomes extremely important in this context.

4.2.1 Proper pricing of irrigation water. Water in the Cauvery Basin at present is almost free. Extensive subsidisation does not even allow cost recovery. In order to make more efficient use of it, it needs to be priced appropriately. As a starting point, at least the operations and maintenance (O&M) costs for irrigation supplies should be recovered. The most efficient mode of pricing that the government can follow is marginal cost pricing. Crop-wise water rates need to be followed, with higher rates charged for crops consuming higher quantities of water. Unless the prices are kept at such levels, efficient demand management of water cannot take place. The pricing mechanism needs to be revised regularly, keeping in view the inflation rates and market conditions. If a condition like the one existing in the basin, where the last revisions took place years ago, continues to persist, the biggest consumer of water would start assuming water to be a "free resource", over which they assume a "birthright". This feeling is already spreading in the basin quite rapidly.

4.2.2 Virtual water imports. A movement towards reduction of area under *kuruvai* rice in Tamil Nadu and *summer* rice in Karnataka can indeed help the process. This is possible by importing rice to the region from places that enjoy the Ricardian comparative advantage of rice production. The average annual water savings and the required virtual water imports are given in Table 10. This is based on the base case of the average annual water use in the 1990s in the two states. We have used the production functions of the 1990s for *kuruvai* in Tamil Nadu and the *summer* rice in Karnataka. The functions are as follows:

$$Y = 4.65^{*}X^{1.04} \tag{14}$$

Table 10. Hypothetical "virtual water" import scenarios.

Scenario	Water savings (in 10^9 m^3)	Production (in '000 kg)	Required rice imports to compensate for the loss (in '000 kg)	Water savings per unit of rice import (m^3 per '000 kg)
Karnataka (Summer rice)				
Status quo	0	465,068.1147	0	0
10% decline in area	0.11241	416,801.0218	48,267.09298	2,328.84390
20% decline in area	0.22481	368,748.4060	96,319.70879	2,334.02959
25% decline in area	0.281016313	344,810.3387	12,0257.77609	2,336.78288
30% decline in area	0.337219575	320,936.0675	144,132.04729	2,339.65715
50% decline in area	0.562032625	226,175.4013	238,892.71340	2,352.65704
75% decline in area	0.843048938	109,995.3116	355,072.80319	2,374.29882
Fully imported	1.12406525	0.0000	465,068.11474	2,416.99057
Tamil Nadu (Kuruvai rice)				
Status quo	0	252,128.8461	0	0
10% decline in area	0.18713	226,677.0076	25,451.83854	7,352.43188
20% decline in area	0.37427	201,253.4913	50,875.35484	7,356.52497
25% decline in area	0.467832273	188,553.4192	63,575.42691	7,358.69652
30% decline in area	0.561398727	175,861.8173	76,267.02884	7,360.96234
50% decline in area	0.935664545	125,193.6325	126,935.21364	7,371.19763
75% decline in area	1.403 496818	62,164.4284	189,964.41767	7,388.20899
Fully imported	1.871329091	0.0000	252,128.84612	7,422.11421

Source: estimated by authors.

for Karnataka *summer* rice

$$Y = 2.1^{*} X^{1.01} \tag{15}$$

for Tamil Nadu *kuruvai* rice.

When a commodity like rice that has been produced elsewhere with water from that area enters the economy (virtual water), the imported rice corresponds to a certain amount of water saved. The results show that water savings per unit of virtual water imports in terms of rice is increasing. Water savings per unit of rice import are much higher in Tamil Nadu, than in Karnataka, owing to the lower productivity of rice in the former.

4.2.3 Cropping pattern changes and crop diversification. This needs to be given serious thought in the region. In a multi-stakeholders' meeting held at the Madras Institute of Development Studies in Chennai in April 2003, with the involvement of the farmers and related stakeholders of both the states, the following was inferred:

"There is a need for a rethinking to diversify crop pattern in the Cauvery delta, in particular Tamil Nadu. The *kuruvai* paddy crop, which falls in summer, often gets into difficulties due to uncertainties and extreme events. The 4 lakh acres of *kuruvai* paddy crop could be substituted by high value dry irrigated crops such as palm (oil) seeds, turmeric, groundnut, gingili, cotton and horticultural crops. This requires thorough research in soil types and climatic conditions and their suitability for various crops. At the same time, *kuruvai* paddy crop could be cultivated where no other crop is possible due to particular given soil conditions." (Janakarajan, 2003)

While virtual water imports through rice imports can help demand management of the existing water, the processes need to be supplemented by the promotion of crops like ragi that need less water. Ragi is already a popular crop in the Karnataka part of the basin, although, not in Tamil Nadu. But, it has excellent nutrient content and high food value. This fact needs to be highlighted properly. The government's initiative is also important. From the policy perspective, it is suggested that ragi should command a competitive price relative to rice. Relative price, in terms of the minimum support prices announced by the central government, already moved in favour of rice in the 1990s. This trend needs to be reversed for Ragi to emerge as an encouraging choice as a staple crop. The region has potential for growing Ragi in Karnataka. What is needed is support for the crop, with properly designed incentives.

5. Concluding remarks

This paper is confined to certain assumed conditions about the production methods used in the Cauvery Basin. It does not consider factors that are not related to water and factors not affecting the scarcity value of water have been explicitly kept outside this paper, except for the "virtual water" processes. The concerns of soil fertility (whether that has changed over time) and other input usage too have not been included in detail into this analysis. Further examination of these factors, therefore, remains for further research. The proposed framework can always be used to explain any type of dispute where a resource is stressed by competing interests, and with extensions and modifications.

There may remain questions relating to the technology. There have been new water management strategies to reduce water inputs for rice and these are steadily coming into the frame. There have been new ways of reducing seepage and percolation, through reduced hydrostatic pressure, by practising either saturated soil culture (SSC), or alternate wetting and drying (AWD) (Boumann & Tuong, 2001). Suggestions about moving towards aerobic rice have also been raised, with respect to water reduction in rice production. So far, experiences of such methods have been associated with a massive decline in yield (De Datta *et al.*, 1973; Westcott & Vines, 1986). Hence, whether such methods should be adopted remains open to debate, considering the amounts of water saving. Recent research in the area of *System of Rice Intensification* is yet to become popular in the Cauvery Basin region.

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