

Institute of Agricultural Policy and Market Research

Economic and Environmental Impacts of Political Non-cooperative Strategies in Water Management: An Analysis of Prospective Policies in the Cauvery River Basin of India

Dissertation

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Abbreviations

BC	Bonus constraint
BCF	Billion Cubic Feet
BCM	Billion Cubic Meters
CADA	Command Area Development Authority
CGWB	Central Ground Water Board
CMC	Cauvery Monitoring Committee
CRA	Cauvery River Authority
CVM	Contingent Valuation Method
CWDT	Cauvery Water Dispute Tribunal
CWP	Centre for water policy
ECCB	Electoral Constituencies in Cauvery Basin
ENVIS	Environmental Information System
HC	Honorarium constraint
IC	Incentive constraint
INR	Indian Rupees
ISWD	Inter State Water Disputes Act
KBJNL	Krishna Bhagya Jal Nigam Limited
KRS	Krishna Raja Sagar
KWh	Kilowatt-hour
MBA	Market By Agencies
P-A	Principal- Agent
PC	Participation constraint
SRI	System of Rice Intensification
TMC	Thousand Million Cubic feet
TN	Tamil Nadu
UTM	Universal Transverse Mercator
Winbugs	Windows- Bayesian inference Using Gibbs Sampling
WTP	Willingness To Pay
WUA	Water User Association

1 INTRODUCTION TO THE HISTORY OF THE CAUVERY WATER CONFLICT

1.1 Evolution of a water conflict

Since ages human existence depends on the relationship that societies have with water resources. It can be seen that most of the ancient civilisations were built around rivers. In the current era, water influences almost all facets of economic development like agriculture, industries, employment, housing, health and several other sectors. But the present development of water resources are taking place in a context of limited resources, rivalling priorities, increasing demands and institutional limitations (Uitto and Duda, 2002). This is especially true for developing countries, though it is a common pattern all over the world. In addition, global climate change, causing shifts in spatial and temporal rainfall patterns, has added to the existing woes (Ansink and Ruijs, 2008). The escalating scarcity of water is exacerbating conflicts over transboundary water resources. Their management poses a number of challenges to politicians, planners, administrators and scientists. Another interesting point is that economic and population growth in developing countries like in India and China is exerting further pressure on already stretched resources; and water may become more and more a limiting factor in these countries if development of appropriate institutional structures and investments on relevant technologies are not taking place. In this scenario, an interstate water conflict by the federal states in India sharing the Cauvery River is discussed. It is to be noted that the disagreement among these Indian states is over the quantitative allocation of available water in the river, like in many transboundary rivers of the Middle East, Africa and America and not on the water quality issues as predominant in Europe. It will be interesting for the reader if we traverse through the historical development of this water dispute, explain current political dilemmas in this introductory chapter.

1.2 Historical background

Examining the historical train of events that led to the conflict under study can furnish meaningful insights over current political stand points and may throw some light on possible management measures. The Cauvery river dispute is virtually tied up to the history of south India over 800 years even though the last 100 years are the most significant. The construction of embankments and canal irrigation in south India can be traced back to the Gupta era (300-500 A.D), evident from the Fa Hsien's (Buddhist Pilgrim of fifth Century from China) travelogue. Even in a time before Guptas, a stone masonry structure across the

Cauvery River (Cauvery Anicut) was constructed by an early Chola King, Karikala Cholan (200 A.D) to regulate the flood waters. The irrigation heritage of Pallavas (600 A.D.) was flourished during the time of a later Chola dynasty (985-1205 A.D) when a quite advanced irrigation system including anicuts (a dam made in the course of a stream for the purpose of regulating the flow of a system of irrigation) and tanks were constructed. The Cauvery anicut, mentioned earlier, was strengthened during the British Regime in 18th century. All these irrigation facilities were primarily targeted to enhance the cultivation of rice in the Cauvery delta region. (Bosu, 1995 and Choudhary, 2000).

Turbulent times in water sharing in Cauvery basin date back to early 1800 when there was a correspondence between the Madras state which was under the British rule and the Mysore, which was a princely state (Wodeyar Kings), notably on the latter's use of waters from Cauvery river against the interests of the former (1807 AD). The delta region of Cauvery was under Madras state of British Empire while the upstream area belonged to the princely state of Mysore at that time period. From 1831 to 1881, the two states were under British rule and irrigation projects continued during early years, but abandoned in 1877 due to a severe famine in that year. The irrigation projects were recommenced after the transfer of Mysore to Maharaja's administration in 1881 (Anand, 2004).

The irrigation developments in Mysore state again raised the concerns of Madras state and an official discussion between the two states was organised during 1890 which resulted in "Irrigation Works in Mysore State - The Madras - Mysore Agreement" in 1892. This agreement restricted the Mysore government in constructing new reservoirs or anicuts (water diversion structures) in the area under her command with out the prior consent of Madras presidency. While the Madras state was not allowed to refuse the consent unless the proposal to construct new reservoirs violates its already acquired or the actually existing prescriptive rights on water. (Bosu, 1995 and Anand, 2004). After a while, both governments were of the opinion that the 1892 agreement is against their interests as the Mysore observed that her irrigation development is throttled by the undefined prescriptive rights of Madras. Meanwhile Madras state was concerned of getting completely deprived of any share of available water surpluses.

Under the auspices of the 1892 agreement, both Madras and Mysore states started developing new irrigation projects during the 1900s and 1910s, where the Mysore came up with the Kannambadi dam project while Madras was considering the Cauvery Mettur project. The Kannambadi dam which is now known as Krishna Raja Sagar (KRS) was proposed in two stages where the initial one would create a water storage capacity of 11 billion cubic feet (0.31 billion cubic meters) while

the second stage would result in additional 30 billion cubic feet storage (0.84 billion cubic meters). In accordance with the agreement, both riparian states were exchanging details of the proposals and the Madras state gave consent to the first phase. But it had strong reservations against the construction of second phase. Following the discussions during 1910 and 1924, a new agreement was signed by the riparian states. Even though the new agreement allowed Mysore to construct the second phase of KRS dam, it insisted on limiting the irrigated area to 110,000 acres (44,000 ha) and in turn the Madras state agreed to limit the new irrigation area of the Mettur dam to 301,000 acres (120,400 ha). Mysore Govt. had to ensure the flows to Madras according to the annexure of the agreement, but was allowed to expand the effective storage capacity to 45 billion cubic feet (1.27 billion cubic meters) in the Cauvery basin. This agreement had an expiry time of 50 years (Anand, 2004).

After the Indian independence from British rule in 1947 and division of the country into linguistic-based federal states in 1956, the Mysore princely state fell in the state of Karnataka while most of the areas under Madras state of British India belonged to the state of Tamil Nadu. Development of irrigation infrastructure started soon after its formation in Karnataka and the land area under irrigation grew around four times compared to the stipulated area in 1924 agreement by 1970. This affected the interests of the farmers in the Tamil Nadu state where the irrigated agriculture was already well developed and hence the Tamil Nadu (TN) Govt approached Government of India to refer the dispute to a tribunal under the Inter State Water Disputes Act (ISWD Act, 1956). By this act, the Govt. of India can delegate the issue to adjudication by the tribunal only if the negotiation between the two riparian states failed to settle the issue. There had been 21 rounds of discussion between the states since 1971 without any outcome and hence the Cauvery Water Disputes Tribunal constituted in 1990 following ISWD act by the request of TN in 1986. TN wanted Karnataka to restrict her new irrigation projects and ensure a timely and adequate water releases. By the early 80s itself, the scenario of Cauvery water sharing was different in many ways. Now the Kerala state claimed 100 billion cubic feet (2.83 billion cubic meters) of Cauvery water, Karnataka state demanded 465 billion cubic feet (13.16 billion cubic meters) and the union territory of Pondichery claimed 10 billion cubic feet (0.283 billion cubic metes) and Tamil Nadu was of the opinion that 1897 and 1924 agreements must be followed (Anand, 2004).

Soon after the constitution of the tribunal, Tamil Nadu approached the tribunal for an interim award for water releases from Karnataka, and the tribunal gave an interim award in 1991 according to the Indian Supreme Court directive. This entitled 205 billion cubic feet (5.8 billion cubic meters) of annual release of water

from Karnataka to Tamil Nadu. The award also included a monthly and weekly schedule of water to be released to Tamil Nadu along with a stipulation of barring expansion of irrigated area in Karnataka. In turn, Karnataka passed an ordinance to make the tribunal award void. The Supreme Court of India intervened and the order of the tribunal was upheld making the ordinance invalid. These developments caused widespread violence and damages in Karnataka. In 1995, when the monsoon rain failed in Karnataka, the states did not follow the interim order of the tribunal and subsequently the state of Tamil Nadu approached the tribunal for the immediate release of 30 billion cubic feet of water. The tribunal examined the case and ordered Karnataka to release 11 BCF of water. Karnataka informed the tribunal that it is not in a position to release 11 BCF water to Tamil Nadu and hence Tamil Nadu approached the Supreme Court. The Court in turn asked the prime minister to make a political decision and all parties agreed on releasing 6 BCF water to Tamil Nadu.

In 1997, two new bodies viz., the Cauvery River Authority (CRA) and Cauvery Monitoring Committee (CMC), were formed by the Government of India. The CRA included the prime minister of India and chief ministers of Kerala, Karnataka, Tamil Nadu and Pondicherry; while the CMC was a body of engineers, technocrats and other experts for surveillance of ground situation in Cauvery and it had to report to CRA. In 2002, the monsoon failed once again in Cauvery basin and the Indian Supreme Court, in response to Tamil Nadu's plea, ordered (October, 2002) a release of 1.25 billion cubic feet of water per day unless CRA revised it. Subsequently the CRA revised the requirement to 0.8 billion cubic feet of water per day. But in response to widespread protests in Cauvery basin districts in Karnataka against release of Cauvery water, Karnataka stalled the release of any water to Tamil Nadu defying the CRA order. Subsequently the Supreme Court ordered Karnataka to comply with the CRA order which the Karnataka state government refused. In the following legal action, Karnataka resumed the release of water to Tamil Nadu in the month of November (Wikipedia, 2007). It seems to be a never ending story.

The development of irrigated areas in both states during the described period is quite important. Before 1924, the irrigated area in Cauvery basin (under Madras presidency then Tamil Nadu) was around 1.52 million acres. According to the Cauvery tribunal, the area developed by Madras/Tamil Nadu state under the clauses of 1924 agreement was 0.62 million acres which together constituted an area of 2.14 million acres. Further, an area of 0.206 million hectares developed by Tamil Nadu outside the provisions of 1924 agreement was held under merit by the tribunal along with 125 thousand acres under the minor irrigation category. So the total area under irrigation considered under merit by tribunal is 2.471 million

acres (1 million hectares). In case of Karnataka, the area before 1924 is only 0.344 million acres. The area developed under the clauses of the 1924 agreement is 0.724 million acres which together constitutes 1.068 million acres (according to Cauvery Water Dispute Tribunal). An area of 0.691 million acres of irrigated area which is now developed by Karnataka outside the provisions of 1924 agreement and 0.126 million hectare under minor irrigation are also considered under merit by Cauvery Water Dispute Tribunal (CWDT-VOL V, 2007). The total irrigated area considered in Karnataka is 1.885 million acres (0.76 million hectares). Bosu, 1995 reports that the irrigated area in Karnataka was 2.14 million acres (0.85 million ha) in 1990 while irrigated area under Tamil Nadu stood at 2.58 million acres (1.03 million ha). In summary, it can be seen that the historical development of irrigation in Cauvery basin caused the development of irrigated area and pattern that the River can not sustain under present technical and institutional conditions.

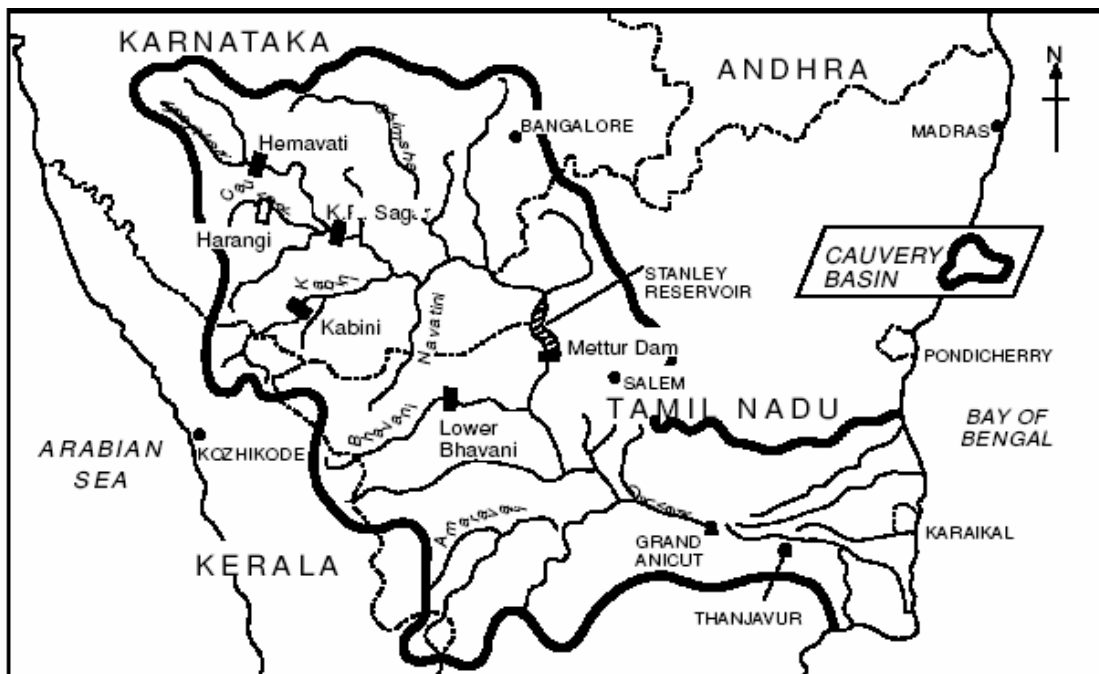


Figure 1.1: Map of Cauvery River basin showing its main tributaries and reservoirs

Source: Bosu (1995)

1.3 Research questions

With this historical sequence of irrigation development of the study region in the background, the study poses the following research questions

- 1) How can one explain the political non-cooperation in Cauvery water sharing between the states?
- 2) What are the environmental and economic impacts?
- 3) Can we design institutional measures to alleviate them?

1.4 Objectives

1. Providing a theoretical explanation of the non-cooperative strategy of Cauvery basin states in water sharing
2. Assessing the environmental costs of the water sharing dispute in the agricultural sector
3. Designing water rights trade as an institutional arrangement and analysing its potential in alleviating the economic and environmental cost of mutual noncooperation between the basin states.

1.5 Organisation of the study

Chapter 1 presented the evolution of the Cauvery river water conflict from a historical perspective and introduced the research questions and objectives of the research work. Subsequently, Chapter 2 introduces the research setting by giving an overview of geographical and climatic characteristics as well as the surface and the ground water supply and demand conditions of the river basin. This chapter also describes the primary data collection exercise and presents the farm and farmer characteristics to make the reader aware of the agricultural setting in the research work. Chapter 3 explores various instruments that can be used for transboundary water allocation decisions. The pros and cons of legal, economic and geographic approaches in transboundary water sharing are discussed here. In addition, the chapter discusses the features of large irrigation systems in developing countries in general and the Indian context in particular and lays the background for further discussion. It also gives an overview on various environmental externalities of inefficient water allocation. Chapter 4 builds upon the historical perspective presented in the chapter 1 and discusses why there is a need to decouple water allocation and the net benefits that the water represents, for a politically acceptable solution of the water sharing issue. This chapter unravels the economic motives behind the political stand points of farmers and

presents the prisoners dilemma that is faced by parties facing electoral competition in constituencies in Cauvery River basin area. Subsequently, the chapter 5 discusses the possibility of using the economic instrument of initial water allocation and trading of water rights to decouple water rights from actual water use. A concept of interstate water trade among water user associations is developed to reduce the transaction costs. In order to coordinate the responses of farmers in a water user association to water right prices a revenue sharing contract mechanism is designed. The coordination mechanism ensures that farmers take effort to generate water surplus that can be traded to other water user association facing water deficit. The final water allocation is decided by the water market and it can lead to Pareto optimal increase in benefits compared to the status quo allocation in the river basin, only if the cost of purchasing the additional water rights is lower than cost of the using the alternative source of water by the WUAs of the demand side i.e. groundwater. Hence the Chapter 6 estimates the cost of ground water extraction including the externality costs. The investment cost of setting up bore wells and pumping machinery is amortized and added with the externality costs of over- extraction to calculate the demand price of water rights. The externality is calculated using spatial hedonic regression of the depths of water table on farmland prices. The econometric estimation of the spatial hedonic regression is carried out in a Bayesian framework. In order to examine whether the supply prices are the demand prices estimated in Chapter 6, a numerical simulation of the revenue sharing contract is conducted in the chapter 7 to estimate supply prices. Various parameters of the contract are estimated using secondary and primary data. The estimated demand and supply prices of water is used to examine whether the water market can generate Pareto optimal benefit for both the states. Finally the Chapter 8 compiles the results and reveals the road map to an equitable, efficient and sustainable water allocation among the basins states by establishing initial water rights and an interstate water right market where water user communities are allowed to trade water rights.

2. RESEARCH DESIGN, DATA COLLECTION AND DESCRIPTIVE STATISTICS

2.1 Description of study area

The Cauvery River is a major river in peninsular India (see Rao, 1975), flowing from Western- Ghat mountain ranges to the Bay of Bengal through the Mysore plateau and the Cauvery delta crossing Kerala, Karnataka, Tamil Nadu states and the union territory of Pondicherry. The 800 kilometers long river has a catchment area of 81155 Km² in which 34273 Km² lies in Karnataka, 44016 Km² in Tamil Nadu and 2886 Km² in Kerala. The river flows around 400 kilometers in Karnataka state, 60 kilometers along the Karnataka -Tamil Nadu border and around 230 kilometers in Tamil Nadu. Cauvery River has 21 principal tributaries in which 9 are located in Karnataka and 12 in Tamil Nadu. Important tributaries that join Cauvery in Karnataka are the Harangi, the Hemavathi, the Shimsha, the Arkavathi, the Lakshmithirtha, the Kabini and the Suvarnvathi. After entering into Tamil Nadu, Cauvery meets the Mettur reservoir. Below Mettur, principal tributaries in Tamil Nadu viz. the Bhavani, the Noyyal and the Amaravathi joins Cauvery. Then the river continues its flow until upper anicut where the Cauvery bifurcates to a southern branch which retains the name Cauvery and a northern branch called Coleroon and both joins again at grand anicut. From the grand anicut, the Coleroon continues its flow in north east direction and joins Bay of Bengal while the Cauvery divides further into Cauvery and Vennar and then subdivides into a number of branches and finally reaches the Bay of Bengal (CWDT-VOL I, 2007 and Rao, 1975). A flow diagram of Cauvery River up to lower anicut is given in figure 2.1.

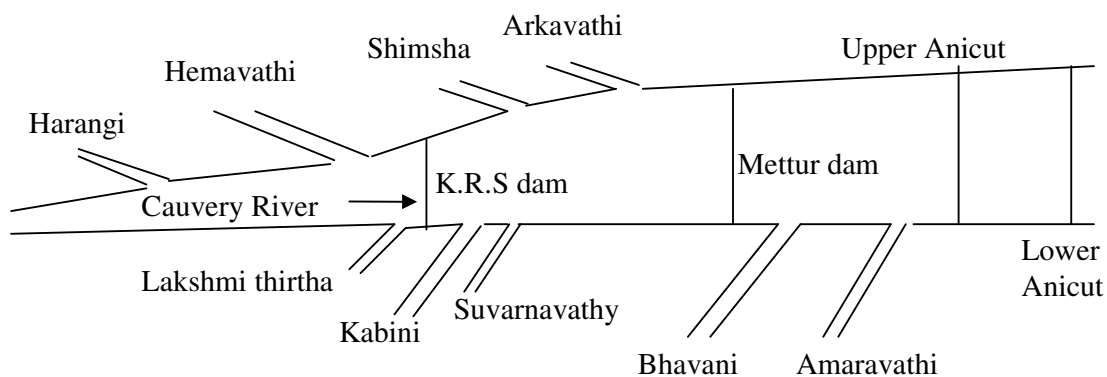


Figure 2.1 : Flow digram of Cauvery River

Source: Rao, 1975

It is to be stated that this study confines to the major riparian states i.e. Karnataka and Tamil Nadu; though Kerala and Union territory of Pondicherry will be occasionally mentioned.

2.1.1 Rainfall and weather conditions

The climate of the Cauvery basin can be categorized into four distinct seasons i.e. colder weather period (January to February), hot weather period (March to May), south-west monsoon period (June to September), and north-east monsoon period (October to December) (CWDT-VOL III, 2007). During the colder weather period, mean daily minimum temperature ranges from 8.6°C in mountainous areas to 22.8°C in plains of the basin while the mean daily maximum temperature ranges between 20.4 °C to 35.5 °C during hot weather period. The Western side of the catchment receives mainly south-west monsoon while the eastern part receives rain mostly from north east monsoon. The rainfall pattern is very diverse along the river basin ranging from 574 to 5411 mm per annum. Coorg district of Karnataka receives 2400 mm rainfall annually while the Mysore and Mandya districts receive 691 mm and 762 mm, respectively. In the case of Tamil Nadu, south-west and north-east monsoon contributes almost equally up to the confluence of Cauvery with Amaravathy River (around 390 mm each) while from the confluence with Amaravathy to confluence it with Bay of Bengal, the north-east monsoon contributes a mean rainfall of 527mm while south-west monsoon contributes 299 mm on an average. (CWDT-VOL III, 2007 and India water portal, 2007). So it can be seen that the Cauvery basin up to Mettur reservoir is under the influence of south-west monsoon while the area downstream to Mettur reservoir is under the influence of north-east monsoon. This pattern is evident in the average rainfall patterns provided below. It has major implications for seasonal water availability and requests.

Figure 2.2 shows that Mandya and Mysore districts are benefited from south-west monsoon (peaking of rainfall in June to September) while figure 2.3 shows the predominance of north-east monsoon (peaking of rainfall in October to December) in the selected taluks (local administrative unit) of Trichy, Pudukkottai and Tanjavore districts of Tamil Nadu downstream to Mettur dam.

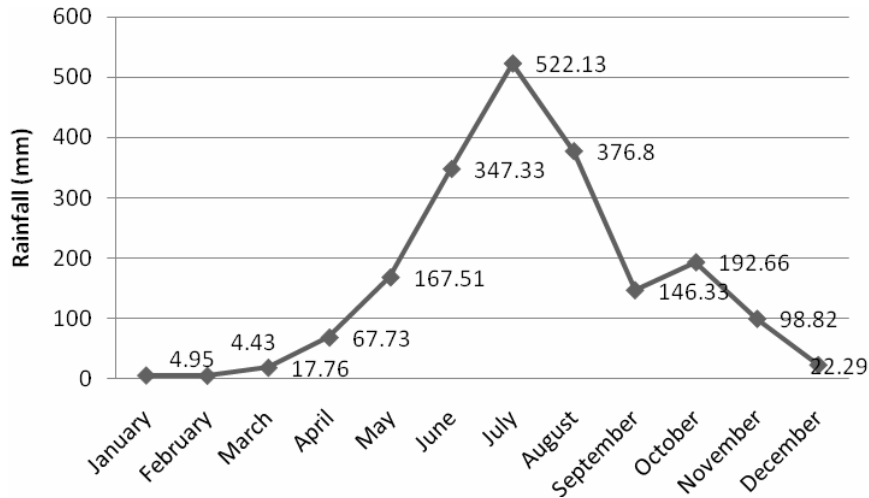


Figure 2.2 Average rainfall (mm) per month in selected taluks of Mandya and Mysore districts of Karnataka for the time period 1901-2002.

Source ; India water portal (2007)

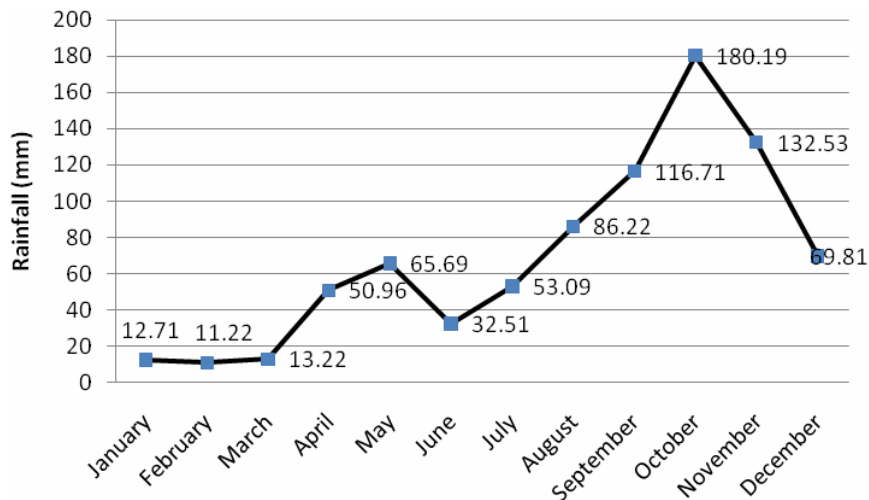


Figure 2.3 Average rainfall (mm) per month in selected taluks of Trichy, Pudukkottai and Tanjavore districts of Tamil Nadu (mm) for the time period 1901-2002.

Source ; India water portal (2007)

2.1.2 Surface water availability in Cauvery basin

The estimated average annual water potential of Cauvery River is 21.36 billion cubic meters (BCM) while the estimated utilizable surface flow is 19 BCM per annum. The live storage capacity of completed river water projects in the basin is 8.60 BCM and development of additional 0.27 BCM storage capacity is

progressing (Central Water Commission, 2005). The Cauvery water disputes tribunal (CWDT-VOL III, 2007) reports slightly different figures, i.e. the gross storage capacity of all reservoirs in Cauvery basin is 9.34 BCM (330 TMC) while the live storage capacity is 8.78 BCM (310 TMC). In this 5.8 BCM gross storage capacity (5.57 BCM live storage) is built before 1972.

2.1.2.1 Storage structures

The irrigation infrastructure in the Cauvery basin is well developed in both, Karnataka and Tamil Nadu by major, medium and minor irrigation projects as well as diversion structures. It should be noted that the local irrigation systems are classified into three groups in India according to their command area viz. Major (more than 10,000 hectares), Medium (2000 to 10000 hectares) and Minor (less than 2000 hectares). The major and medium projects are handled by state government agencies (like irrigation department), while the minor irrigation projects are handled by local bodies like village panchayats. Before the existence of reservoir systems, a number of anicut schemes (water diversion structures) existed in Karnataka. Currently there are 25 anicut schemes of which 15 are located above the Krishna Rajasagar reservoir (see Figure 2.1) and 10 are located downstream to the reservoir. Together, these anicut schemes irrigate 80,000 hectares. The major irrigation projects in Karnataka are Kabini, Harangi, Hemavathi and Krishna Rajasagar reservoirs while medium sized projects are Kanva, Suvarnavathy, Arkavathy, Yagachi, Marconahally, Votehole, Manchanabele, Taraka, Gundal, Nugu and Uduthorehalla. The major reservoirs (viz. Kabini, Harangi, Hemavathi reservoirs) are located in the tributaries of Cauvery River with the same name, while the Krishna Rajasagar reservoir (KRS) is located in the main Cauvery river. In case of medium sized projects, Kanva and Marconahally projects are located in Shimsha tributary, Manchanabele and Arkavathy are located in Arkavathy tributary, Taraka is standing at Taraka tributary of Kabini, Nugu is located at Nugu River in Kabini sub basin, Uduthorehalla is constructed at Palar tributary, Votehole is located at Votehole tributary of Hemavathi and Yagachi is located at Yagachi tributary of Hemavathi. Major irrigation projects viz. Kabini, Harangi, Hemavathi and Krishna Rajasagar (KRS) reservoirs mentioned above have live storage capacities 0.45, 0.23, 1.01, 1.27 billion cubic meters (BCM) and the irrigation potentials of 41225, 43141, 194768, 138173 hectares respectively (as of March/2005). The KRS dam was constructed during 1911 and 1931 while construction of Kabini started in 1959, Harangi in 1964, Hemavathi in 1968 and all were completed during the 10th five year plan period (2002-2007). The current irrigation potential of the medium irrigation projects mentioned ranges from 1245 hectares (Manchanabele) to 21448

hectares (Yagachi). All of these dams were completed by 1989. In addition, the construction of Krishna Rajasagar Right Bank Canal or Devraj Urs canal was started in 1979 and now it irrigates 32375 hectares (CADA, 2005, CWDT- VOL IV, 2007).

The major irrigation reservoirs in Tamil Nadu are Mettur, Lower Bhavani, Amaravathy and Palar-Porandalar, all located in Cauvery and its tributaries of Bhavani and Amaravathy. The live storage capacities of these dams are 2.65, 0.91, 0.11 and 0.04 BCM respectively. These projects were completed by 1970. The Cauvery River in Tamil Nadu forms an extensive delta area of 0.35 million hectares which is directly fed from the Mettur irrigation project. The other irrigation systems fed by Mettur project are the lower Coleroon Anicut system, the Salem-Trichy channels, the Kattalai scheme, the Cauvery Mettur project (Grand anicut canal), the Mettur Canal, the new Kattalai high level canal and the Pullambadi canal. Gross irrigated areas by these canal systems are 0.065, 0.045, 0.034, 0.13, 0.018, 0.008, 0.0088 million hectares, respectively. Above Mettur reservoir, the Thoppaiar reservoir scheme serves 2120 hectares. In the Bhavani sub basin of Cauvery basin, the Kodivery anicut system, the Kalingrayan anicut system, the lower Bhavani reservoir project and some minor irrigation schemes are located. The largest area coverage in this sub basin is by the lower Bhavani reservoir which irrigates around 0.083 million hectares. The irrigation system in Amaravathy sub basin of Cauvery consists of old Amaravathy Channels, Amaravathy, Palar-Pondalar, Vattamalaikarai-Odai, Kodanganar and Nanganjar reservoir projects as well as minor irrigation schemes. Amaravathy reservoir project irrigates around 0.0084 million hectares while Amaravathy channel feeds around 0.013 million hectares. Other mentioned reservoir projects in this sub basin irrigate between 2500 and 4,000 hectares. Finally, Noyyal sub basin of Cauvery has Noyyal river channels irrigating 5990 hectares, Noyyal reservoir project irrigating 3885 hectares and Orathupalayam reservoir irrigating 4209 hectares (CWDT-VOL IV, 2007).

The average run off at Krishna Raja sagar reservoir is estimated (using historical flow data by CWDT) to be 6.213 BCM or 219.4 Thousand Million Cubic feet (TMC) at 50 percent dependability. At the same time the yield at Mettur reservoir is calculated at 14.280 BCM or 507.8 TMC at 50 percent dependability. The government of Tamil Nadu estimated the contribution of the Karnataka or Mysore part of the river basin to be 11.7 BCM or 413 TMC while the Mysore assesses the contribution of their catchment to be 11.55 BCM or 408 TMC. The following graph (figure 2.4) shows historical flows in the Cauvery River at lower Coleroon anicut which is considered as the downstream measurement point of the Cauvery River basin. Data sets on gross water yield at this point of the river provided to

Cauvery Water Dispute Tribunal (CWDT-VOL III, 2007) by Karnataka (KN) for the time period between 1901 and 1972 and Tamil Nadu (TN) for the time period between 1935 and 1972 are shown separately. Average yield of KN series is 22.43 BCM (792.3 TMC) while TN series is 21.7 BCM (766.98 TMC). The average yield of Cauvery River, assessed by the CWDT, is 20.9 BCM or 740 TMC at 50 percent dependability. Considering this estimate, it can also be stated that 42 per cent of total flows can be stored in various storage structures, built in the river.

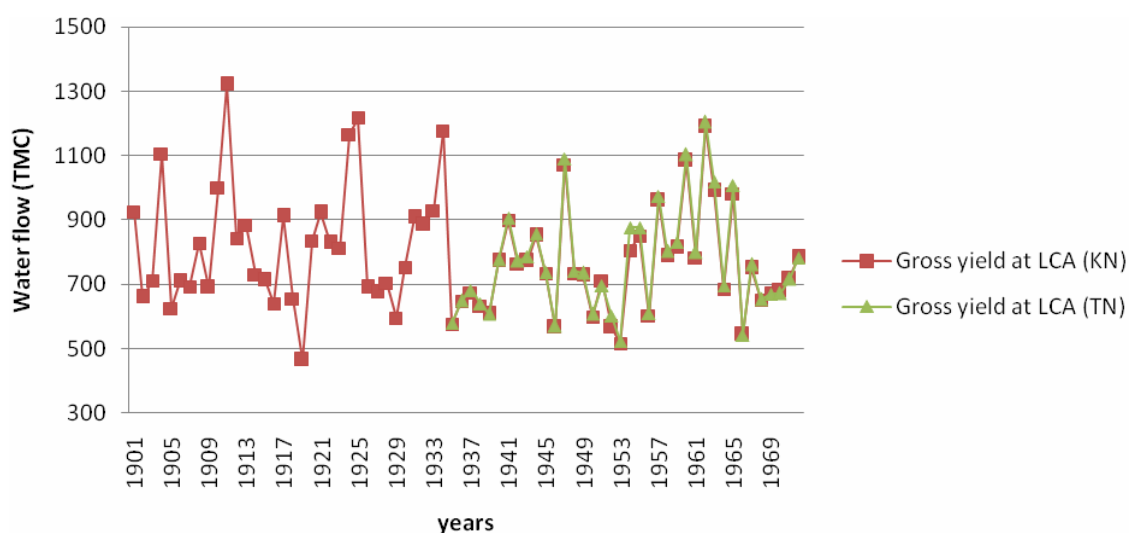


Figure 2.4: Historical flows in Cauvery River at lower Coleroon anicut

Source: CWDT-VOL III (2007)

2.1.2.2 Tank irrigation

The minor irrigation systems (Predominantly tank irrigation) in Cauvery basin of Karnataka covers an area of 133,546 hectares; while in Tamil Nadu part of the basin, the area under minor irrigation is 139,414 hectares. Irrigation tanks are one of the main minor irrigation sources in both states. Palanisami (2006) defines an irrigation tank *as a small reservoir constructed across the slope of a valley to catch and store water during the rainy season so it can be used for irrigation during the dry season*. In the tank irrigated tracts of the Cauvery basin, farmers raise a single paddy crop depending on the filling of the tank each year. Irrigation systems in Mysore state, at the onset of the century, were mainly the system of tank irrigation and the diversion canals (anicut) from the Cauvery River. Tanks in erstwhile Mysore state irrigated 81,000 hectares while diversion channels managed to cover only half the area. It reminds us the importance of tanks in the irrigation system of that time. Tank irrigation was a widespread practice in Tamil Nadu also where north-east monsoon was the main source of water for tanks

(Palanisami, 2006). Area irrigated by tanks declined all over the country from 4.1 million hectare (13.1 % of the total irrigated area) in 1970-71 to 3.1 million hectare (5.7 % of the total irrigated area) in 1997-98. The decline of tank irrigation is due to a multitude of factors including 1) widespread groundwater pumping facilities catering individual farmers in a tank area, 2) increase in operation and maintenance cost of tanks and 3) inability of tanks to serve the command area due to siltation resulting from destruction of forest and vegetation in catchment etc. The increase in operating costs in Tamil Nadu is around 135 INR (26 INR to 161 INR) per hectare at current prices, though the increase is not substantial in constant prices (Only 10 INR at 1980-81 prices) (Palanisami, 2006). The decline in tank irrigation is evident from the decline in its share of total irrigated area in Tamil Nadu as given below (Figure 2.5). Apart from the reasons quoted above, the historical reason for the decline of tank irrigation in Tamil Nadu (cited by Mosse, 1999) is the shift in management of village level resources during colonial period. In early British period, the government operated through the village elites who invested fairly steadily in community resource management system for honours and local position. Later the centralised public work department, put in place by the British Government which was directly involved in resource management, made the local chiefs and big men to shun from investing in water resource management in villages. This shortage in investment was never made up by the public works machinery, which led to decline in tank irrigation.

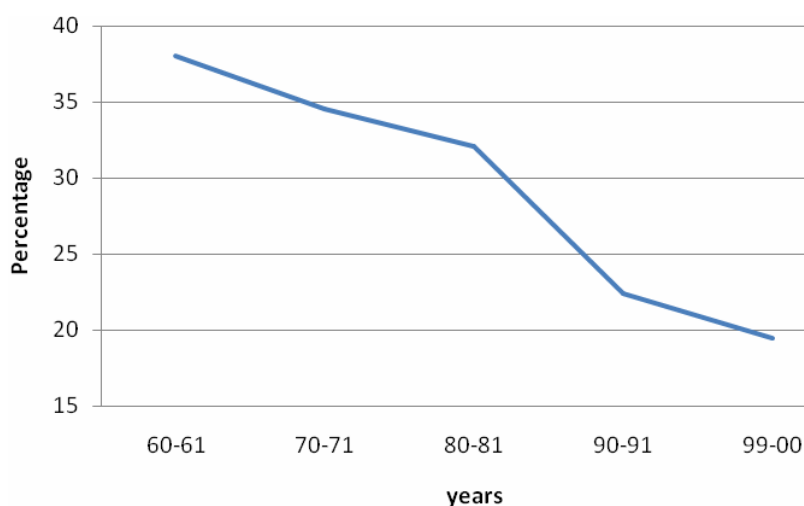


Figure 2.5: Tank irrigated area in Tamil Nadu in percentage terms over decades

Source: Palanisami, 2006

2.1.2.3 Ground water availability

All over India, the well irrigated area increased from 11.9 million hectares (38.3%) to 30.9 million hectares (56.6%) during the time between 1970 and 1997. Unlike the surface irrigation systems, the investment on ground water irrigation is from private agencies; i.e. farmer's own money is invested to establish dug or bore wells. The use of public funds for this purpose is limited. Currently, farmers in India have invested around US \$12 billion in ground water irrigation which is comparable with the public sector investment on surface irrigation in India which is around US \$ 20 billion (Shah *et.al*, 2003). The total ground water extraction in the country is currently around 150 cubic kilometers annually. This ground water extraction is taking place mainly through 13.14 million energized pumps in the country (Shah *et.al*, 2003).

Replenishable ground water, available in whole Cauvery basin, is estimated at 12.30 billion cubic meters out of which 10.45 billion is available for irrigation. The current groundwater draft is estimated at 5.78 billion cubic meters, notably at the current level of ground water development of 55.3% of the total capacity (CGWB, 2005). In Karnataka, underground hard rock formation and discontinuous nature of aquifers make well digging a risky affair. But in Tamil Nadu, the use of dug and bore wells for ground water development is common and, importantly, most parts of the state are experiencing lowering of ground water levels due to over exploitation (CGWB, 1995). The dependence of Karnataka on ground water for irrigation is 35 % while it is 47.2 % in case of Tamil Nadu (measured for the year 1994-1995). Total ground water abstraction from *Cauvery delta* area during 1971 to 1983 is represented in figure 2.5



Figure 2.6: Water abstraction from Cauvery delta region

Source: CWDT-VOL III (2007)

In 1989, it was estimated that the groundwater extraction from Cauvery delta region had been 1.01 BCM in the old delta area [0.80 BCM at Cauvery sub basin and 0.21 BCM in Vennar sub basin] and 0.32 BCM in the new delta area (grand anicut area) through 41,800 energized pumps, 15000 diesel pumps and 100,000 non energized irrigation facilities and domestic wells. The number of energized pumps in Tamil Nadu currently is 13.14 million, though exact figures on Cauvery delta or basin are not available. There are different estimates on replenishable ground water availability in Cauvery delta region. The available estimates show a range from 0.815 to 1.1BCM (28.8 to 39.2 TMC) for the old delta region and 0.64 to 0.92 BCM (22.77 to 32.6 TMC) for the new delta region. It can be speculated that the ground draft in Cauvery delta was nearing its potential in 1989. Due to over exploitation, many of the wells require deepening in frequent intervals or have to be abandoned in short periods of time leading to lose of capital invested. In costal areas like Nagapattanam in Tamil Nadu, excessive ground water development has led to sea water intrusion and has rendered the water unfit for irrigation purposes (CWDT-VOL III, 2007).

Extraction of ground water is directly connected with energy use. Various governments in the Cauvery basin have taken a generous policy towards energy supplies for groundwater irrigation. Zero tariff schemes in Tamil Nadu and subsidized tariffs of Karnataka are prominent examples. Usually a flat rate is charged for every irrigation pump depending on its maximum pumping capacity rather than the measured energy use. Due to energy subsidies, Tamil Nadu farmers pay less than 1500 INR for irrigating one hectare of land while a similar farmer in Bangladesh pays 4800 INR (6000 takka) (Shah, 2004). This created the situation of a ground water irrigation boom hurting the energy economy. It is estimated that the pumping of 150 cubic kilometer of ground water in the whole India uses subsidized energy worth US \$ 4.5-5 billion every year (Shah et al., 2003). In Tamil Nadu, electric power is available for farmers 14 hours a day for 365 days a year. Electricity consumption per tube-well increased from 2583 KWh/year in 1980s to 4546 KWh/year in 1997-98 indicating the increase in wasteful pumping and falling ground water levels (Shah *et al.*, 2007). Agriculture in Tamil Nadu consumed 6,910 million units of electricity in 1996-97 which has increased to 10,358 million units by 1.8 million pumps in 2005-06 according to available statistics (Hindu, 2007). In Karnataka, the state allocated 18000 million INR from its budget as subsidy for the power consumed by agricultural pumps (Government of Karnataka, 2007). Nevertheless, it is to be noted that some part of inefficiency in power distribution systems is attributed to agricultural consumption of electric power in India; it keeps up the inefficiency figure at 33 percent. This gives way to siphon out the agricultural subsidies to unintended

benefactors (Monari, 2002). Another important point is the cross subsidization of agricultural power by higher power tariffs to commercial and industrial sectors; they cross subsidize the agricultural and domestic sectors. This cross subsidization is to the tune of 50.2 % all over India in 1998-99 (Gulati and Narayanan, 2000).

Recharging ground water in the Cauvery delta has a conspicuous connection with the surface irrigation from Mettur reservoir. It is stated that a shallow aquifer of Cauvery delta will be filled after two months after commencing the flow of water through canals originating from Mettur reservoir (CWDT-VOL III, 2007). This causes the water obtained during peak monsoon season (north-east) in October and November flow directly to the sea without getting stored in underground aquifers (CWDT-VOL III, 2007). The pattern of rainfall characterized by intense showers for short period of time, causes less groundwater recharge from north-east monsoon. In addition, research conducted in Srilanka indicates that a catchment area of 34 acres is needed for 1 acre of ground water irrigated area to replenish the used groundwater. As the groundwater irrigation spreads spatially, the availability of catchment of recharge is becoming lesser every year (Shah *et.al*, 2003).

2.1.3 Agriculture in Cauvery Basin

The occupation of around 60% rural dwellers is agriculture in the Cauvery basin. Gross cultivable area in the basin is 5.8 million hectares which is around 3 per cent of the country's cultivable area. Major crops grown are paddy (*Oryza sativa*), finger millet (*Eleusine coracana*) and sugar cane (*Saccharum officinarum*). Major paddy producing areas are Tanjore, Thiruvavur and Nagapattanam districts in Tamil Nadu where more than 0.15 million hectares of land area are allocated to paddy. Mysore and Mandya districts in Karnataka have 0.06 and 0.09 million hectares of cultivated area under paddy (Kharif season). The Tanjore district produced 0.4 million tonnes of rice (not raw paddy) while Nagapattanam produced 0.25 million tonnes in 2005-06. In Mandya, yield differences between irrigated and unirrigated paddy were of 0.6 tonnes on average while the mean yield was 3.1 tons under irrigated condition. Productivity of paddy is low in India compared to China or Egypt. The mean productivity of paddy in India is 3 tonnes per hectare while China produces almost double the tonnage per hectare (6.2 tonnes). In case of finger millet, Tumkur (0.2 million hectares), Mandya (0.07 million hectares), Mysore (0.08 million hectares) and Hassan (0.08 million hectare) in Karnataka are major producing districts. All figures refer to Kharif season of 2005-06. Salem and Dharmapuri districts (0.01 and 0.02 million hectares) in Tamil Nadu also have large areas under finger millet cultivation. The Mandya district

produced 0.15 million tonnes of finger millet in 2005-06 (2 tonnes/ hectare) where the average yield difference between irrigated and unirrigated finger millet was 0.2 tonnes. Coming to sugarcane cultivation, Mandya and Mysore districts in Karnataka are prominent cultivators with 0.013 and 0.008 million hectares respectively. In Tamil Nadu, Trichy district has a sugarcane cultivation area of 0.0026 million hectares. Mandya district produced 1.3 million tonnes of sugarcane in the agricultural year 2005-06 with a mean productivity of 111 tonnes per hectare. (Directorate of Economics and Statistics (Karnataka), 2007 and Department of Economics and Statistics (Tamil Nadu), 2006).

2.1.3.1 Rice cultivation

In the Mysore state (later Karnataka), paddy cultivation before 1928 was limited to the areas where irrigation via anicuts and tanks were available. After the construction of Krishna Raja Sagar reservoir, large-scale irrigation facilities were made available making paddy the major crop, especially under its command area. In addition, farmers started sugarcane crop cultivation in some of the irrigated tracts. Nevertheless, irrigation authorities tries to discourage paddy in new irrigation projects in Karnataka and growing of finger millet, groundnut or other light irrigated crops are encouraged (CWDT-VOL III, 2007). The same is done in old project areas, evidently, when there is inadequate rainfall. A single paddy growing season (i.e. Kharif from middle of June until the middle of November : 145-150 days) is followed in most of the basin areas in Karnataka.

In Tamil Nadu, paddy cultivation was mainly in the Cauvery delta region fed by grand anicut canal and other anicuts before 1928. Due the construction of Mettur dam and copious flows from Cauvery River due to favourable clauses in 1928 agreement, paddy cultivation became the dominant activity in the Cauvery basin area in Tamil Nadu. There are three rice growing seasons in these areas below Mettur reservoir. They are named: Kuruvai, Thalady and Samba. In Kuruvai, a short duration paddy crop (105 days) is cultivated while in Thalady medium a duration paddy crop (135 days) is taken up. Kuruvai and Thalady are as subsequent crops in the same field while Samba is a single long duration paddy crop (150 days), which will not be followed by another rice crop. Kuruvai is starting normally in June utilizing the south-west monsoon and flows in Cauvery and harvesting is in August-September before the onset of north-east monsoon. The second crop of medium duration, planted after Kuruvai, known as Thalady utilizes the north-east monsoon and is harvested in January-February. In other areas a long duration crop ('Samba') as single crop is grown which starts in July-August and is harvested in December-January (CWDT-VOL I, 2007). In all over Tamil Nadu, rice productivity is quite high as compared to the rest of India. A

status paper on rice cultivation in India places 27 out of 28 rice growing districts in Tamil Nadu state as areas of high productivity while only 14 out of 27 rice growing districts of Karnataka state are classified under the same category (DRD, 2002).

2.1.3.2 Rice crop and water use

All over Cauvery basin, the method of transplanting of rice crop is popular over the method of direct seeding. Transplanting needs the preparation of a nursery of rice seedlings and is more labour intensive than direct seeding. For the nursery, the land is ploughed two or three times in dry conditions and puddled by ploughing in standing water of 2-3 cm. Then the land is levelled and raised beds of 1-1½ meter breadth and convenient length is formed. In the raised beds germinated seeds are broadcasted. In the initial stages water is kept at saturation levels and water level is increased gradually to 2-3 cm and maintained over the nursery period. The 2- 3 weeks old seedlings are transplanted to puddled and levelled main field. Conventionally, rice is planted with 3-4 seedlings per hill creating a dense vegetation of 50-100 plants per square meter. Water management is an important activity in rice farming. Land preparation by puddling requires large quantity of water i.e. approximately 15 percent of total water requirement). During the crop growth period, continuous flooding of the fields is practiced conventionally, using 1000-2000 hectare millimeters of water (10000 -20000 cubic meters per hectare) in Cauvery basin. This figure can be compared with finger millet which requires 2000-2500 cubic meters per hectare and sugarcane which demands 20000-25000 cubic meters under conventional farming in the Cauvery basin area (Shankar *et.al*, 2003). It should also be noted that the efficiency of flood irrigation can be as low as 20 per cent. Another objective of continuous flooding is weed control in paddy fields which is conventionally supplemented with labour intensive hand weeding (Bindraban, 2001, Uphoff, 2003).

As the monsoon rainfall in Cauvery basin can be erratic, especially at the starting of the season, there is a need of supplemental irrigation for land preparation of paddy fields (CWDT-VOL I, 2007). In addition, supplemental irrigation is required at various stages of rice crop. The critical stages of rice crop are the seedling stage, tillering phase, panicle initiation to flowering, milk dough stage, reduction division stage and primordial initiation. Exposure of paddy crop to water stress at these stages may cause reduced root formation, reduced tillering, reduced number of fertile grains, reduced number of filled grains, steep yield decline (-70%) and reduced numbers of grains respectively (Palanisami *et al.*, 2003). The recommended practice of water management for paddy crop in

Cauvery basin is to irrigate at 5 cm level, one day after the disappearance of ponded water in the field. But many farmers keep their farm under flooded conditions (10-20 cm) during the entire cropping period, which is a wasteful practice (Vijayakumar *et al.*, 2006). The water saving by the recommended practice is estimated to be 31 percent in Kharif and 48 percent in summer (Palanisami *et al.*, 2003).

2.1.3.3 Rice as a staple food crop

Rice is the main part of the local diet. Rice primarily contains carbohydrate in the form of starch (70-75 %) and contains a minimum of protein (7%). The energy value of 100 gram rice is 345 kilo calories. Tamil Nadu accounts for 7.4 percent of India's rice production while Karnataka has a share of 3.4 percent. The productivity of rice in Tamil Nadu is 3.48 tonnes per hectare while Karnataka stands at 2.56 tonnes per hectare (see above) (Agmarknet, 2007).

2.1.4 Agricultural water requirement

The affidavit submitted to CTWD by Tamil Nadu in 2004 shows that the net irrigation water, required for supporting present cropping pattern at current technology, is 12.57 BCM (444.15 TMC) for 1.04 million hectares under canal irrigation, 1.95 BCM (68.9 TMC) for minor irrigation in 0.137 million hectares and 0.283 BCM (10 TMC) to cover reservoir evaporation losses. In case of Karnataka, the affidavit submitted in 2003 puts the net irrigation water required to be 10.80 BCM (381.71 TMC) for 1.02 million hectares and demanded 0.79 BCM (28.158 TMC) for proposed projects irrigating 0.08 million hectares. The cumulative demand of both states alone is 26.42 BCM (933 TMC) where the total flow in Cauvery River is 20.95 BCM (740 TMC) at 50 percent dependability. A breakup of the net irrigation water requirement in respective command areas of each irrigation project in Tamil Nadu and Karnataka is available. The sub-basin-wise claims of Tamil Nadu and project wise claims of Karnataka are given in the pie charts below (CWDT-VOL V, 2007).

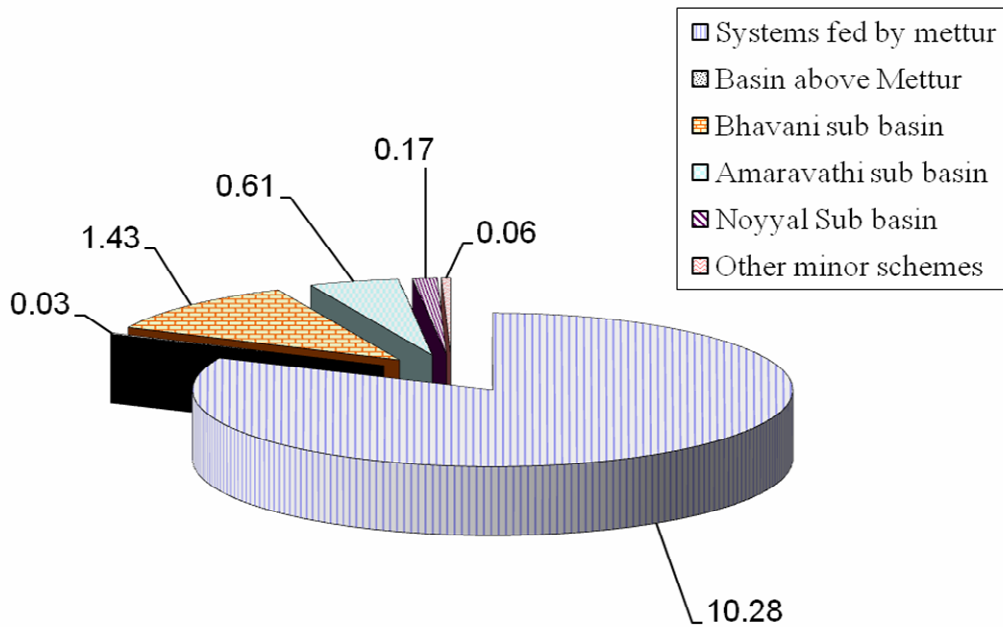


Figure 2.7 Sub basin wise breakup of Tamil Nadu’s claim on water requirement in billion cubic meters

Source: CWDT-VOL V, 2007

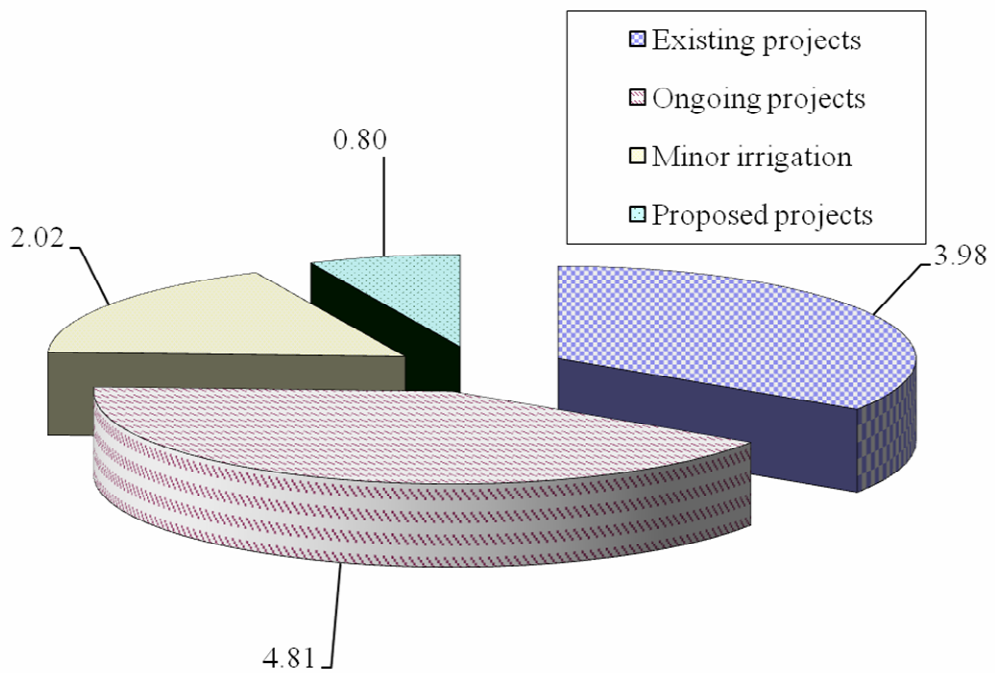


Figure 2.8: Sub basin wise breakup of Karnataka’s claim on water requirement in billion cubic meters

Source: CWDT-VOL V, 2007

In addition, Kerala state is claiming 2.38 BCM (100 TMC) and the union territory of Pondicherry is claiming 0.254 BCM (9 TMC) from the available flow of Cauvery River.

2.1.5 Domestic and industrial demand for water

2.1.5.1 Urban and rural domestic demand

According to a 1981 census, 31.2 % of population was urban dwellers in the whole basin area, which has been substantially increased during the last decade. This pattern is also evident from the trend of population density in Bangalore city which has increased from 882 persons / square kilometer in 1981 to around 3000 persons/ square kilometer now. This rapid urbanization is exerting additional pressure on already stretched water resources in the basin. In 1991, the drinking water supply requirement for the Bangalore city was 0.41 BCM (14.51TMC) including the ongoing drinking water supply projects at that time. It is estimated that 0.85 BCM (30 TMC) of water will be the ultimate water requirement for the city. As there is no data available on water requirements for human and livestock in both, the rural and urban areas, of the Cauvery basin, CWDT estimates very rough figures of 0.49 BCM (17.22 TMC) for Karnataka and 0.62 BCM (21.98 TMC) for Tamil Nadu. It should be noted that 50 percent of this requirement is assumed to be met with ground water and 80 percent of the water used for domestic purposes returns to the river or its tributaries and hence the consumptive use on this category is 0.05 BCM (1.75 TMC) for Karnataka. The CWDT considers only 1/3rd of the Bangalore city on its estimation as 2/3rd of city is lying outside the basin. Similarly for Tamil Nadu, the consumptive domestic use of water is estimated at 0.062 BCM (2.2 TMC) (CWDT-VOL V, 2007).

2.1.5.2 Industrial demand

There are various projections on industrial water requirements of Tamil Nadu from Cauvery River. According to the information furnished by Tamil Nadu to CTWD in January 1993, the industrial water requirement from the River was reported to be at 0.062 BCM (2.2 TMC). From this as a trend forecast, the water requirement is estimated to be 0.21 BCM (7.43 TMC) in 2001 and 0.38 BCM (13.63 TMC) in 2025. But in the supplementary information, provided in March same year, it is put at 0.14 BCM (4.98 TMC) in 1993, 0.40 BCM (14 TMC) in 2000 and 1.048 BCM (37 TMC) for 2025. CTWD estimates the industrial water demand of TN to be 0.28 BCM (9.96 TMC) by 2011. It is assumed that 97.5 per cent of water used in Industries flows back to the river and hence the consumptive use is put at 2.5 percent. In addition, the thermal power station at Mettur is utilizing 54.34 cusecs (1.54 cubic meters per second) of water and returning

45.282 cusecs (1.28 cubic meters per second) leading to a consumptive use of 0.008 BCM (0.28 TMC) annually.

The industrial water use Karnataka in 1990 stood at 0.91 BCM (3.20 TMC) and is projected at that time to be 0.16 BCM (5.71 TMC) in the year 2000 and 0.227 BCM (8.02 TMC) in 2025. The CTWD puts it at 0.18 BCM (6.40 TMC) in which 0.073 BCM (2.58 TMC) will be met from ground water. Using the same assumption applied to Tamil Nadu case, the consumptive use from the river is estimated at 0.003 BCM (0.10 TMC). To summarise, the total domestic and industrial consumptive use requirement to be met from Cauvery river water estimated by CTWD is 0.052 BCM (1.85 TMC) for Karnataka and 0.077 BCM (2.73 TMC) for Tamil Nadu. It is evident from these figures that industrial water demand in Cauvery Basin area is still a fraction of irrigation water demand, which in quantitative terms, account less than 3 percent of the latter.

2.2 Research design and data collection

Apart from data available from secondary sources, collection of primary data was organized through a stratified random sampling procedure. 240 farmers, belonging to 24 villages from 24 blocks of 8 Cauvery River basin districts in Karnataka and Tamil Nadu, were interviewed. The primary survey was undertaken during the time period between July 2005 and September 2005. The surveyed districts, blocks (or Taluks) and villages are given in the table below. The selected districts in Karnataka are Tumkur, Hassan, Mysore and Mandya while the selected districts in Tamil Nadu are Trichy, Tiruvarur, Tanjore and Nagapattanam. The canal irrigated areas in the districts selected Karnataka are 49, 286, 971 and 882 square kilometers respectively. In the case of selected districts in Tamil Nadu, the canal irrigated areas are 450, 1389, 1564, 1278 square kilometers respectively.

Table 2.1: Names of villages, blocks and districts sampled in Karnataka

State	Karnataka			
District	Tumkur	Hassan	Myore	Mandya
Village (Block)	Moorkanahally (Gubbi)	Kachenahalli (C.R.Patna)	KG Koppalu (Piriyapattana)	Murukanahalli (K.R. Pete)
	Nonavinakere (Tiptur)	Huchina Koppalu (Hole Narasipura)	Nellurupala (Hunsur)	Kadathnal (S.R.Patna)
	Madehalli (Turuvekere)	Vaddarahalli (Arkalgud)	Kastur Gate (K.R. Nagar)	Mavina Koppalu (Mandya)

Table 2.2: Names of villages, blocks and districts sampled in Tamil Nadu

State	Tamil Nadu			
Districts	Trichy	Tiruvarur	Tanjore	Nagapattanam
Village (Block)	Paachur (Mannachanallur)	Alangudi (Valangaiman)	PasupathiKovil (Papanasam)	Palakurichi (Keelaiyur)
	Pallividai (Lalgudi)	Peraiyur (Needa mangalam)	Enathi (Pattukottai)	Thetenpettai (Kilvelur)
	N.Sanathanur (Ananthanallur)	Meelavasal (Mannargudi)	Pulavankadu (Orathnadu)	SembianMadhavi (Nagapattanam)

The geographical positions of the sampled locations are documented in the table below. The latitude, longitude and distance of each sampling location from the tail end sampling location ‘Sembian Madhavi’ village in Nagapattanam district are also given in the table.

Table 2.3: Geographical information of study locations

Village	District	Longitude	Latitude	Distance in Kilometers
Alangudi	Tiruvarur	79.37	10.88	53.2
Peraiyur	Tiruvarur	79.41	10.76	39.3
Meelavasal	Tiruvarur	79.43	10.66	28.0
Paachur	Trichy	78.4	10.53	116.8
Pallividai	Trichy	78.43	10.54	113.7
N.Sanathanur	Trichy	78.38	10.5	118.7
Palakurichi	Nagapattanam	79.46	10.4	1.1
Thetenpettai	Nagapattanam	79.46	10.47	6.7
Sembian Madhavi	Nagapattanam	79.46	10.41	0.0
Pasupathi Kovil	Tanjore	79.28	10.93	61.1
Enathi	Tanjore	79.31	10.43	16.6
Pulavankadu	Tanjore	79.26	10.61	31.2
Mookanahalli	Tumkur	76.59	13.2	440.8
Nonavinakere	Tumkur	76.33	13.09	453.2
Madehalli	Tumkur	76.42	13.09	445.9
Kachenahalli	Hassan	76.19	12.51	426.5
Huchina Koppalu	Hassan	76.13	12.46	429.1
Vaddarahalli	Hassan	76.03	12.48	439.5
KG Koppalu	Mysore	76.12	12.29	420.4
Nellurupala	Mysore	76.16	12.14	408.5
Kastur gate	Mysore	76.18	12.29	414.7
Murukanahalli	Mandya	76.18	12.29	414.7
Kadathnal	Mandya	76.39	12.27	393.9
Mayannana Koppalu	Mandya	76.49	12.3	386.5

2.3 Overview of the farmer sample

A pre-tested interview schedule was used for the survey which covered various aspects of socio-economic, geographic, cultivation, water use and environment related information. In the whole sample of 240 farmers, small farmers (<2 hectares) accounted 72 percent, and 28 percent were large farmers (>5 hectares). Among all farmers, 34 percent farmers held less than 1 hectare.

2.3.1 Age structure

It is interesting to look at the age structure of the farmers which gives the picture of an aging farmer population. The median age of the sample is 45 while the median age of the total population in India is 24.9 (Wikipedia, 2008). The age profile of the sampled farmers is given below in figure 2.8. The median age of sampled farmers in Tamil Nadu and Karnataka are strikingly similar i.e. 45 and 46 respectively.

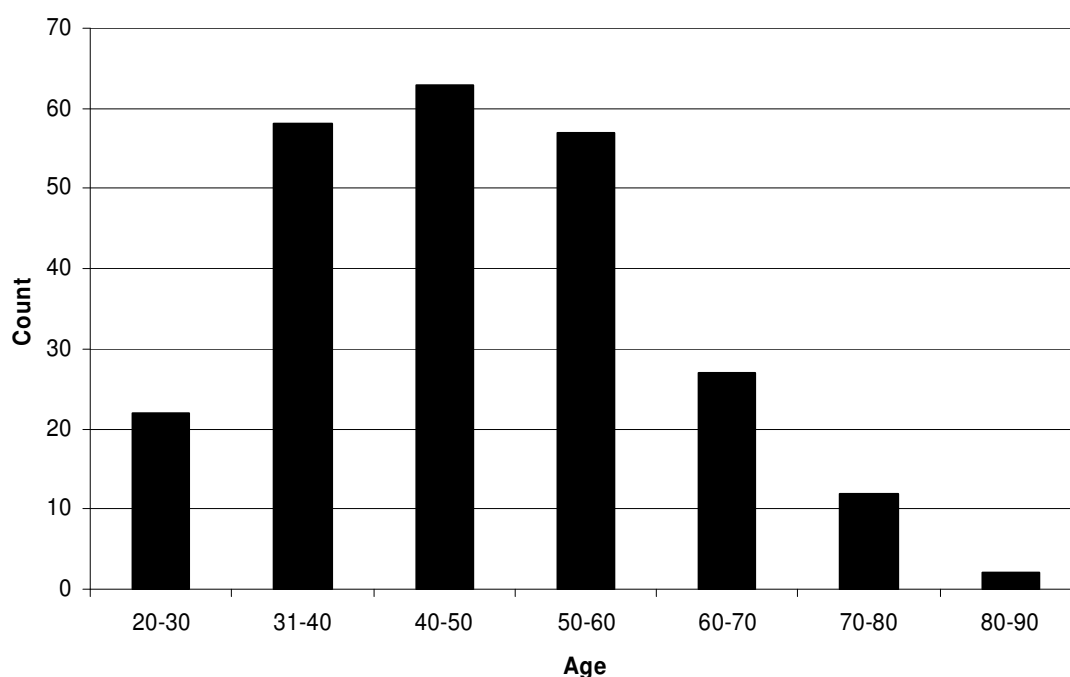


Figure 2.9: Age profile of sampled farmers

2.3.2 Education and family size

At the education front, the average education level of the sample farmers is 8 years of schooling, showing their relative inability to take up other enterprises. There are 24 farmers with college education and only 1 farmer with a master degree in the sample. The average farm size of the college educated farmers tends to be higher at 12.6 acres or 5 hectares. On the other extreme, there are 25

farmers without any formal education in the sample and the average size of their farm holdings is 1.4 hectares. The farmers had relatively larger family size and the average stood at 5.4 persons per family. Average family size of large farmers tended to be a little larger than of small farmers i.e. 5.45 and 5.31 respectively. The biggest family was of the size 16 and the smallest was of 2 members.

2.3.3 Land characteristics and land prices

As mentioned earlier the Cauvery basin farmers predominantly fall in the category of small farmers which is reflected in the median size of the sample farmers at 1.6 hectares. The mean of the sampled farmer holdings is 2.3 hectares. Distribution of the sample farm sizes in the dataset is representative of fragmented farmlands in a developing country with an average size of 2.3 ha and a standard deviation of 3.1 ha. Distribution of farm sizes is depicted in figure 2.9. The holding sizes tended to be higher in sampled farmers in Tamil Nadu as compared to Karnataka. Coming to the relative position of the land holdings with respect to water channels, 34 percent of the sample farmers are located in head reaches, 27 percent in the middle reaches and 39 percent in tail end with respect to nearest irrigation canal. It can also be seen that 71 percent of the sample farmers are located in plain lands, while 29 percent are located in valley slopes. Coming to the soils, farmers reported predominantly red sandy loam soil in Karnataka and black clayey loam soil in Tamil Nadu. A majority of the farmers, participated in the survey, opined that the soil quality of their farms is good to moderate quality (92%), though they expressed more confidence in soil quality in Tamil Nadu than in Karnataka.

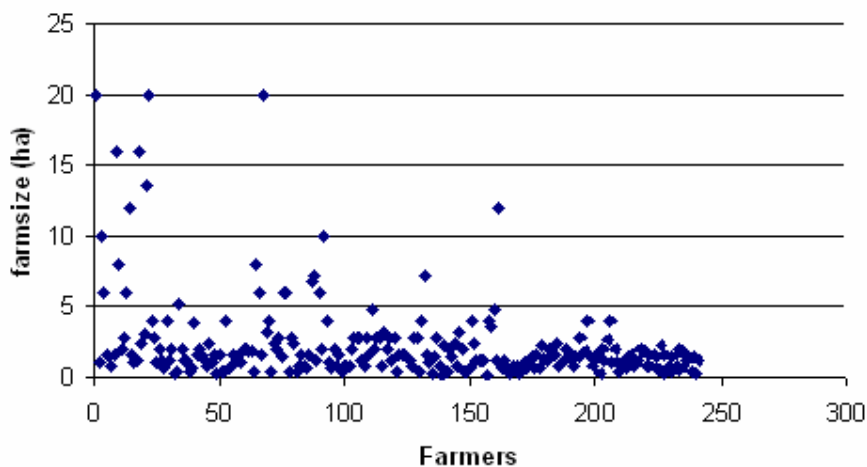


Figure 2.10: Farm size distribution of sampled farmers

Reasonable market approachability for the farmers in both states is evident from the average distance to road and average distance to nearest local market. From the sampled farms, the average distance to the nearest road is 1.3 kilometers and the average distance to nearest market is 8 kilometers. The agricultural land market is well developed with land prices ranged from 0.05 million to 2.5 million Indian rupees per hectare. Different kinds of land leasing arrangements were observed. The leasing price in terms of money ranges from 2500 to 10000 INR per hectare in the study area, though higher figures are reported for sugarcane. In some of the sampled villages, the leasing price is fixed as 50 percent share of the paddy output or as a fixed portion of output i.e. 6-9 bags of rice per acre (15-22 bags per hectare). In some other areas, fixed quantities of paddy (800-1300 kilograms per hectare) are used as the rent. It is to be noted that the agricultural land market in the sampled villages of Nagapattanam district is reported to be dysfunctional due to sea water intrusion in groundwater making it unfit for irrigation.

2.3.4 Crops

Major crops grown by the sampled farmers in Karnataka are paddy, sugarcane, pulses and finger millet while paddy, sugar cane, banana are found to be the major crops in Tamil Nadu. Paddy was the major crop of sampled farmers in both states. It is observed that some farmers go for crop rotations such as paddy-pulse (Eg: paddy-groundnut), paddy-banana, paddy-sesame in Tamil Nadu while paddy-finger millet, paddy-sorghum, paddy-pulse, sugarcane-paddy rotations are recorded in Karnataka. Some farmers (14%) allowed their farming land to be fallow in the first season.

2.3.5 Comparative picture

A comparative picture of farmers surveyed from Karnataka and Tamil Nadu can be obtained from the table 2.4. Farmers differ in education though the age structure and family size are comparable. Tamil Nadu farmers have better accessibility to local markets while Karnataka farmers have better access to roads. Land prices are comparatively higher in Karnataka in comparison than in Tamil Nadu. The average figures on selected characteristics of farmers and farms of each state from the sample survey are given in the table along with the t-statistic that checks whether the differences in average figures are statistically significant.

Table 2.4: Comparative statistics of sample farmers in Karnataka and Tamil Nadu

Variables	Tamil Nadu	Karnataka	t- value
Age	47 years	45 years	1.19
Education	9 years*	7.5 years	2.77
Family Size	5.3 members	5.5 members	-0.67
Slope of farm	2.65 (index)	2.62 (index)	0.37
Distance (Market)	6.8 kilometers*	9.2 kilometers	-2.15
Distance (Road)	1.74 kilometers*	0.85	4.04
Soil (Quality)	1.46 (index)*	1.67 (index)	-2.27
Farm area	3.08 hectares*	1.52 hectares	4.08
Land Price / ha	320792 INR	453707 INR	-4.11

2.3.6 Water use

Surface irrigation is available in all sample locations; though farmers have increased the dependence on groundwater sources over the years. The sampled farmers follow the system of flood irrigation in Paddy except three farmers who switched over to a system of rice intensification (SRI) mode of cultivation where intermittent irrigation is practiced. In case of sugarcane, furrow and ridge irrigation systems were practiced. The 124 farmers, sampled in Tamil Nadu, had 87 bore wells, of which 7 wells were dysfunctional; while in Karnataka 45 wells were owned by 120 farmers out of which 13 were dysfunctional. The chapter 6 presents the investment cost of well irrigation in detail.

Farmers of the Cauvery delta region plan the farming operations according to the release of water from Mettur dam which is opened normally on 12th of June every year. This date coincides with the first cropping season. Delays in release of water in the canals may lead to loss of crop as water availability is critical in the initial stages of rice crop. The uncertainty of farmers over canal water availability can be represented by comparing the actual opening date of Mettur dam with the normal opening date of 12th June. The deviation in days from 1993-94 to 2002-03 is given in the chart (Figure 2.9) below.

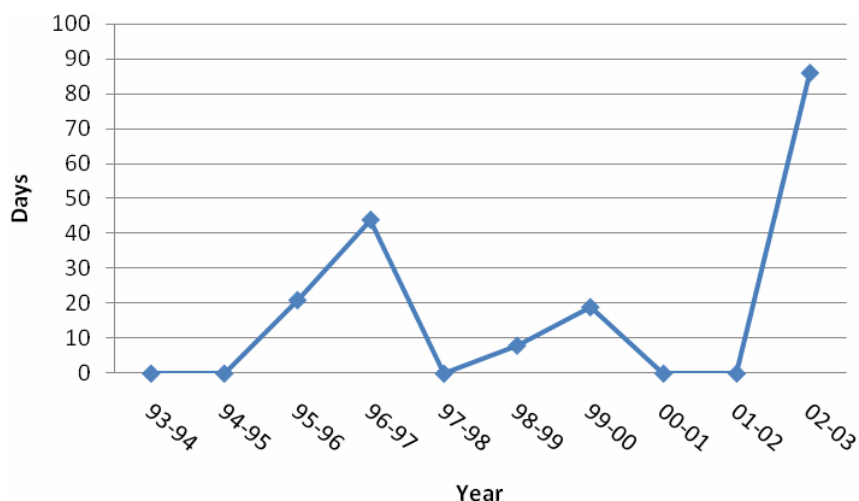


Figure 2.11 Deviation of date of water releases from Mettur dam from normal date of 12th June

Source: Chief Engineer, Water resources organisation, Chennai

Though the the normal date of release of water from dam is fixed at 12th of June, the schedule is strictly followed only 5 times in 10 years between 1993 and 2003. The delay in 2002-03 has gone upto 86 days. It should be noted that the duration of first crop (Kuruvai) is only 105 days. Due to uncertainty of water delivery in Cauvery canals, many of the farmers switched over to ground water sources by drilling bore wells or digging open wells so that they can substitute ground water for surface water.

2.3.7 Credit availability

Farmers in the sample availed credit from both, formal and informal sources. It has to be noted that 131 out of 136 farmers availed credit in the sample borrowed less than 100,000 INR. The scatter plot (figure 2.9) on interest rate and credit size, depicted below, shows that most of the borrowers pay a nominal interest rate between 7 and 15 per cent per annum. The chart excludes the largest 5 borrowers.

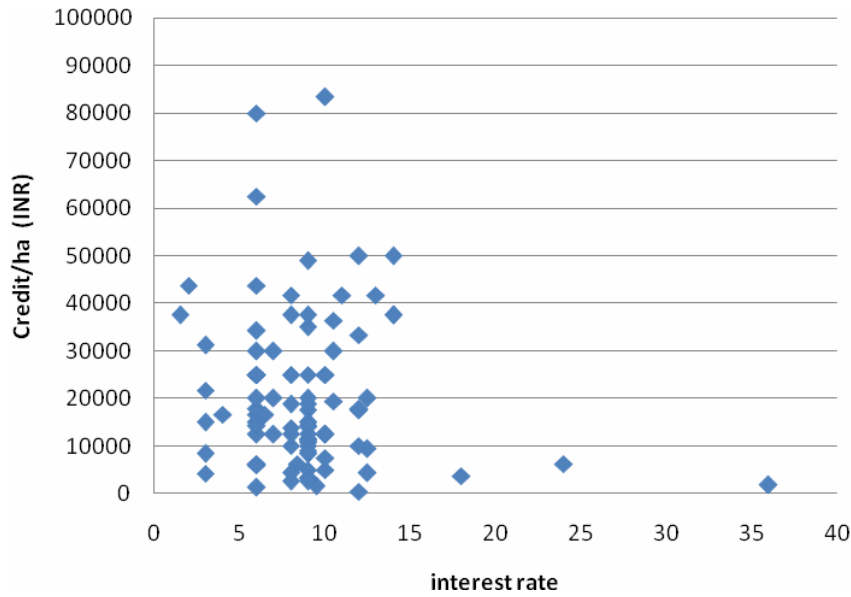


Figure 2.12: Credit size and interest rate of sampled farmers

It can also be noted that many farmers had taken loans for drilling a bore well; and another plot on total credit availed and number of bores is depicted in figure 2.10.

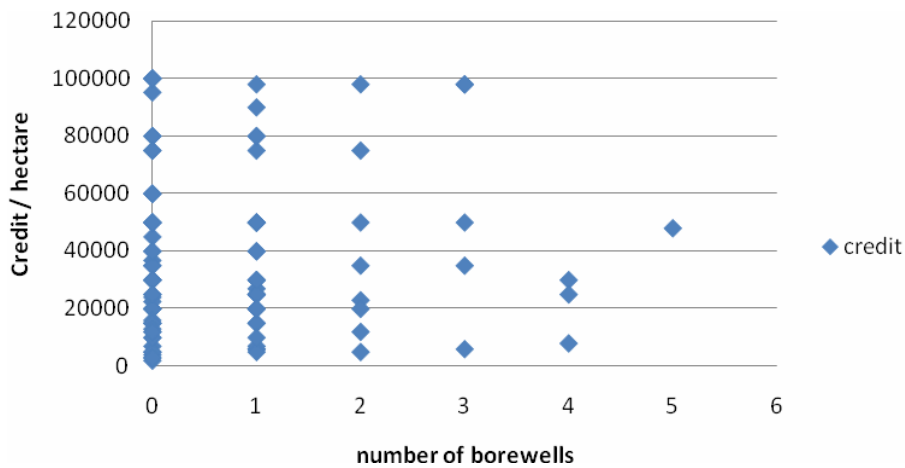


Figure 2.13: Credit size and number of bore wells

2.3.8 Additional information

The schedule also included a willingness to pay exercise and included relevant questions for a hedonic price estimation of water availability in Cauvery basin. The collected information will be presented in detail in relevant chapters.

3. LITERATURE REVIEW ON ECONOMIC AND LEGAL ASPECTS OF TRANSBOUNDARY WATER ALLOCATION

Water sharing conflicts arise when political and hydrological boundaries do not match each other and when a clear dichotomy of cost and benefits of cooperation is perceived (Fishhendler and Feitelson, 2003). Transboundary water conflicts are common as 148 rivers of the world and are crossing geographic boundaries of two countries; while 52 of them flow over more than two countries (Ambec and Sprumont, 2002). In the case of rivers in the developing world, many upstream countries try to divert water from the river basin that they share with downstream countries, notably, for increasing biomass production in agriculture or forestry in order to overcome food insufficiency and poverty. This in turn affects the welfare of downstream countries as it reduces quantity and quality of water available to them (Toset *et al.*, 2000). The same behaviour can be noticed in the states of federal countries like India which share a common river. Interstate water conflicts are also common in United States of America. In the Indian context, numerous interstate conflicts arose after independence as designing of efficient and equitable water sharing mechanisms is still a legal and constitutional challenge (Richards and Singh, 2002). In ameliorating the water sharing issues at national and international level, various streams of thought can be found in the existing literature, (see Beach *et.al*, 2000 for detailed review) that can be classified into legal, geographic and economic approach. The following subsection details the approaches relevant to the river water conflict in question.

3.1 Laws and conventions

3.1.1 International scenario

Till 1950, there were not many laws on transboundary water sharing with the exception of the existence of the bilateral agreements. *The doctrine of absolute territorial sovereignty*, which is one of the earliest legal attempts in this direction, advocates absolute sovereignty of a country on the rivers and natural resources, falling in its geographical boundaries. This principle was first used by U.S attorney general Harmon to justify the position of United States of America in relation to a water dispute with Mexico in 1895; and hence it is known as Harmon doctrine. On the contrary, *the doctrine of unlimited territorial integrity* prohibit the right of a country to change the natural course of a water body if it is detrimental to a lower riparian state (Ambec and Sprumont, 2002; Subedi, 2006). As these doctrines are contradictory by nature, *principal of reasonable and equitable utilisation* emerged as a major guideline in sharing the transboundary

water bodies. This principle is central tenet of Helsinki rules of International Law Association (1966) and the UN convention on the non navigational use of international water courses law of 1997 and is the one which enjoys worldwide acceptance (Gosain and Singh, 2004). The international law making on transboundary water sharing reached its zenith at an UN convention on the law of non navigational use of international water courses (Subedi, 2006). General principles guiding the 1997 convention are equitable and reasonable utilization and participation, obligation not to cause significant harm, general obligation to cooperate, regular exchange of data and information and relationship between different kinds of uses (UN, 2005). In addition to those mentioned above, a number of principles and doctrines can be found in the literature. The *principle of prior appropriation* advocates the protection of existing uses or in other words, it supports the maintenance of the status quo in water utilisation. *Principle of no significant harm* says that any riparian state is entitled to develop the water courses, provided that it does not cause significant harm to other co-riparian states. This principle is criticized as a mere extension of the principle of prior appropriation (Gosain and Singh, 2004). The *Doctrine of correlated rights* keeps more the focus on efficient utilisation of joint water resources than gaining ownership rights (Kilot and Shmueli, 2001). In addition, *the principle of mutual use* which states that a riparian can object the use of water by another riparian unless it is directly compensated and *the linkage principle* where a riparian state may demand compensation in a non related area, are also proposed aiming at water dispute resolution (Kilgour and Dinar, 1995). *The doctrine of correlated rights* keeps the focus more on efficient utilisation of joint water resources than gaining ownership rights (Kilot and Shmueli, 2001). Currently an additional principle viz. *principle of sustainable development and utilisation of waters in international water courses* is also in use (Subedi, 2006).

3.1.2 Indian scenario

The Constitution of India allocates the subject of water into the domain of state legislative subjects (entry number 17 of state subjects in the 7th schedule of constitution of India); but with a clause on interstate rivers (entry number 56 of union subjects in the 7th schedule of constitution of India). The constitution gives power to the central government to enact laws on interstate rivers to adjudicate interstate water disputes. The Interstate Water Dispute Act in 1956 permits any Indian state, which is in dispute with another state in the matter of water use in an interstate river, to request the central government to setup a tribunal for adjudication. The decision of the tribunal is final and binding (Gosain and Singh, 2004). However, in some occasions, states refused to accept the decisions of the

tribunals and in reality, the decision is not binding enough (Richards and Singh, 2002). In addition, River Boards Act in 1956 provides the provision of establishing river boards to regulate and develop the interstate rivers in request of the riparian states (Gosain and Singh, 2004). But ironically, this legal provision is not utilised in India and no river boards have been formed so far (Richards and Singh, 2002). A Cauvery valley authority was in proposition by ministry of Irrigation in 1974 but it was never ratified (Wikipedia, 2007).

Interestingly, In the British period, under the Government of India Act in 1919, irrigation became a provincial but reserved subject, and provincial governments had to get prior approval of Secretary of State for any river water project that may affect the interest of more than one province. Later, the Government act of 1935 placed irrigation as a pure provincial subject but included clauses to refer inter provincial disputes on water projects to Governor General who may appoint a commission to investigate the issue and the decision of Governor General based on the report of the commission was binding for the provinces (Bakshi, 2007).

3.2 Transboundary institutions

In absence of institutions like water sharing treaties defining clear water rights and cite dispute resolution mechanisms, unilateral alterations in water use (by a party, a nation, a state or a province) at basin level can lead to water conflicts. It is observed that co-riparian relationships are more cooperative in the presence of treaties (Giordano and Wolf, 2003). In addition, many researchers and international agencies advocate on basin wide management of water by establishing transboundary institutions. Internationally there are a number of efforts in building up such institutions like the Mekong commission and Rhine river commission.

3.2.1 Transboundary water agreements in India

A number of interstate river water disputes are adjudicated in India under the Interstate Water Dispute Act in 1956. In case of Narmada River which is shared by Madhya Pradesh, Gujarat and Maharashtra states, a tribunal was set up in 1969 to allocate equitable shares among the states involved. In case of this river, 97.59% of the drainage area and 98.75% of the flow contribution belongs to the state of Madhya Pradesh while 0.56% of the drainage area and 0.26% of the flow contribution belongs to the state of Gujarat. 1.5% of the river length was in Maharashtra and 11.5% in Gujarat. The final decision of the Narmada tribunal came into effect in December 1979. In the final award, 67 percent of the water

flow was allocated to Madhyapradesh while 33 percent was allocated to Gujarat (Bakshi, 2007).

The Krishna river basin, which is shared by the states of Karnataka, Madhyapradesh and Andhra Pradesh, was also referred to a tribunal for sharing its water among competing states. The Krishna tribunal gave its award in 1973 which was published in 1976. The tribunal used the *principle of equitable apportionment* and allocated 27 percent of the river water to Maharashtra, 34 percent to Karnataka and 38 percent to Andhra Pradesh out of 58.3 BCM water available in the river at 75 percent dependability. In addition, from the estimated regenerated flows of 1.9 BCM in Krishna River, 0.70 BCM was allocated to Maharashtra, 0.34 BCM to Karnataka and 0.11 BCM to Andhra Pradesh. The tribunal gave preference river projects that are in operation or conceived by the year 1960. In the case of Godavari River, the tribunal started functioning in 1974 though constituted in 1969 as Krishna river allocation was under consideration by the same tribunal. In the Godavari water dispute, Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh and Orissa were the concerned states. The award of the Godavari tribunal was a mere formal consolidation of agreements made by multilateral discussions by the party states. No quantitative allocation of water in the river was made. Instead the river was divided into sub basins and flows from these sub basins were allocated to individual states. It was similar to Indus treaty made by India with Pakistan (Richards and Singh, 2002). In Indus water treaty, 3 east flowing tributaries of Indus (Ravi, Beas and Sutlej) was allocated to India while 3 west flowing rivers (Indus, Jhelum and Chenub) to Pakistan. A system of canals was envisaged to share the surplus in the western rivers. A third party, World Bank was involved in the treaty through Indus basin development fund which financed the construction costs of canals and storage dams to fulfil the conditions of the treaty (Schiff and Winters, 2002).

3.2.2 Negotiation of Cauvery water allocation

A pure conflict situation is existing in the case of the Cauvery River, sharing i.e. allocation of more water to one state eventually means less for the other. As the historical development of irrigation pattern lead to full utilisation of river flows, conflict is unavoidable. Nevertheless, settling the initial allocation of property rights may facilitate a better cooperation among parties. The current conflict can be viewed as an attempt to secure a bigger pie in the initial allocation of property rights on water in the River. The historical developments that lead to the formation of Cauvery tribunal in 1990 have been explained in chapter 1. It can be seen that the importance of tribunal decision is in the settling of the initial

property rights allocation (Richards and Singh, 2002). The tribunal gave the final award on February 5, 2007. According to its verdict, Tamil Nadu will be allocated with 11.86 BCM (419 TMC) of Cauvery water while Karnataka gets 7.65 BCM (270 TMC). The actual annual release of water by Karnataka to Tamil Nadu has to be 5.44 BCM (192 TMC). Further the Cauvery River tribunal allocated 0.84 BCM (30 TMC) water to Kerala and 0.2 BCM (7 TMC) to union territory of Pondicherry (CWDT-VOL V, 2007). Karnataka filed a revision petition to the tribunal as the state viewed the decision of the tribunal be unsatisfactory. Such moves originates from the fact that the initial allocation of property right become the final allocation of the rights as the property rights are not flexible in the absence of institutional mechanisms like water exchange or water trading systems between the states or with in the states.

3.3 Spatial adjustments

Political fragmentation of river basin boundaries which causes spatial discrepancy on benefits and cost distribution among states is one of the main reasons of transboundary conflicts (Fischhendler and Feitelson, 2003). Mechanisms to improve reciprocity of benefits include maintaining hydro-solidarity of basin states despite the costs (Falkenmark, 2001). This approach is limited by the fact that the regions that benefits and regions that incur costs are scattered over the river basin, forming discontinuous mosaic pattern preventing formation of effective water solidarity (Prigram, 1999 in Fischhendler and Feitelson, 2003). Establishment of river water commissions to manage transboundary water allocation is one of the solutions to tackle this issue; though many of the transboundary organisations formed had limited success in managing the water, mainly due to the restrictions imposed by states that incur costs due to cooperation.

Another mechanism for spatial adjustment is the third party involvement by providing financial incentives to the group which may incur cost of cooperation and hence solving the spatial discrepancy (Fischhendler and Feitelson, 2003). Yet another tool of interest is that of linking unrelated issues to the water dispute in order to create a cooperative climate among the groups by balancing the trade offs. Apart from these solutions, it can also be suggested that widening the spatial scale of negotiations can be fruitful. Cooperation of United States of America and Mexico over Colorado and Rio Grande where the allocation issues in Colorado is offset by the transfer of water from Rio Grande is an example of the advantages of advancing the spatial scales (Fischhendler and Feitelson, 2003).

In case of Cauvery River, ambitious plans like linking it to Ganga River got public attention in 1970s though rejected in financial and technical grounds. In 1980, national perspective plan of Government of India proposed linking the Cauvery River to Mahanadi, Godavari, Krishna and Pennar rivers to balance the water deficit and surplus in the rivers of peninsular India. Indian water resources society appraised the scheme to be economically viable and technically feasible in 1996 (Jain *et.al*, 2005). An attempt to simulate a multi reservoir system in Cauvery, Godavari, Krishna and Pennar, in order to analyze the advantages of linking these river basins, was carried out by Jain *et al.* (2005). This study estimates the water deficit in Cauvery delta to be 7.5 BCM and 1.008 BCM in sub basins of Kabini, Arkavathi, Suvarnavathi, Bhavani and Amaravathi. Even if the current ground water draft is included, deficits are huge. This study proposes diverting Godavari river water from Ichampalli dam to Nagarjuna Sagar dam in Krishna River and then to Somasila dam in Pennar River and to Grand Anicut in Cauvery basin so that deficit in Cauvery delta can be managed. The projects are simulated in an engineering perspective while social and environmental impacts of such transfers are not undertaken.

3.4 Economic principles of water allocation

Water sharing mechanisms presented in economic literature concentrates on efficient water allocation; while legal and geographic approaches are based on equitable allocation. Nevertheless, principles that guide the allocation can be economic efficiency or equity, or eventually both. Notice, the instruments in the economic basket include marginal cost pricing, public sector allocation, water markets and user based allocation (Dinar *et al*, 2007). As economists tend to make everyone better off, facilitating competitive market behaviour by establishing enabling property rights and eliminating distortions is often a preferred policy (Just and Netanyahu, 1998). Among them, market allocation mechanisms invite special attention.

3.4.1 Water markets in water dispute resolution

In an Indian context, Richards and Singh (2002) mentions the social contract approach .i.e. deciding on initial allocation of water rights and creating a mechanism to trade these rights and manage externalities. This shall serve to solve existing interstate water disputes. Explicit proposals to form water markets and to solve water disputes can be found in Dinar and Wolf (1994) and Fisher (1995). In the former one, they argue on treating water as a tradable commodity and detail the advantages when countries trade water against technology. By the application of the model to water allocation in middles east, Dinar and Wolf

argues on how Egypt can sell excess water to Israel and Gaza if Israel could sell water saving technology to Egypt.

Many of the water conflicts that are arising from the dispute among states over ownership of water from shared river streams, lakes, aquifers etc. Fisher (1995), address this issue and proves that the water rights and its usage are analytically independent. This approach keeps the focus on economic value of water rather than quantity allocation and hence it does not matter who holds the right but rather who gets the money that the water represents. A country with water entitlements faces the opportunity cost of selling the water to a demanding country and hence will sell water when the actual benefit of using water is lower than that of the gain from trade. In the case of a country that purchases water will do it only if the cost justifies the trade. Hence the dispute on ownership can be translated into a dispute over monetary compensation on water reallocation (Fisher, 1995). Similarly, Ambec and Sprumont (2000) suggest use of side payments in addition to water allocation to distribute welfare among the coalitions or individuals sharing the water resource.

3.4.2 Limitation of existing water market models in developing country context

Though the development of water right markets is advised for a long time as a solution for water allocation issues (Saleth *et al*, 1991), it was criticised on a set of limitations or weaknesses in its usage in developing countries. The major criticisms of establishment of a water market in a developing country can be summarised from the studies of Rosegrant and Binswanger (1994) as well as Gunatilake and Krishnan (2002). Firstly, the bottleneck, pointed out, is the presence of high transaction costs for water allocation and regulation due to small sized farm holdings in irrigation systems in these countries. Secondly the huge investment requirements for conveying water to the locations of demand matter. A third critique is that water trade may cause externalities on third parties, and the fourth one is on probable reduction in agricultural production and income that may result if water reallocation to non agricultural uses is excessive. In their arguments Gunatilake and Krishnan (2002) concentrate on detailing the first criticism while Rosegrant and Binswanger (1994) take on all these arguments and substantiate the possible benefits of water trade within the irrigation sector and for the other sectors in developing countries.

The main arguments that Rosegrant and Binswanger (1994) have put forward on supporting water trade in comparison to other modes of water allocation are (1) the rapidly increasing scarcity of water (2) its high value on reallocation, (3) sizable transaction costs of alternatives like administrative and community

management, (4) political constraints of opportunity cost pricing, (5) possibility of reductions in externalities by the water trading and (6) possibility of investment mobilisation by water users. The same paper downplays the questions of widening disparity between rich and poor due to the water market options and the issue of variability of water supply constraining the usefulness of water markets. One of the suggestions already in this research work is to reduce the transaction costs by assigning property rights of water to user communities instead of farmers, and precisely this argument is pointing towards the potentials of water markets when the characteristic of community management is blended to it. A similar argument is presented by Msangi *et. al* (2006) as well.

3.5. Characteristics of irrigation systems of developing countries: An over view

3.5.1 Technical features

Most of the irrigation systems in developing world are large-scale gravity flow schemes serving small farmers. This includes those in Cauvery Basin. The Water is conveyed from large dams to locations of demand by main canals which later feed the smaller branch canals serving the farmers. Another feature of Asian irrigation systems is that many farmers are not supplied directly from a branch canal but through a neighbouring field (Repetto, 1986).

3.5.2 Institutional setting

Predominantly, irrigation infrastructure is built and operated by public agencies in developing countries. In the last two or three decades, there is drift towards a decentralised and market oriented management of water resources deviating from 'command and control' type of administration though many of the developing countries lag behind (Bjornlund, 2003). One of the driving factors for this change is a shift in lending policies of the World Bank to irrigation projects in developing countries, Earlier the bank supported the infrastructure development through financing large irrigation projects while now a substantial part of the financing is for establishing institutional components for decentralised water management like of creating and strengthening water user associations. The World Bank also promotes establishment of water rights and water market (Plusquellec, 1998).

3.5.2.1 Water pricing

In large scale irrigation systems in developing world serving small farmers, volumetric pricing is an exception rather than the rule. The main bottleneck is the exorbitant transaction costs on constructing channel systems to supply water to individual farms, installing flow measurement devises like weirs and flumes, loss

of irrigation efficiency as measuring devices interrupts water flow, cost of monitoring the water use and huge costs of individual settlement of disputes on water use (Moore, 1989). In addition, one has to look at social and political costs of price reforms. A mathematical simulation model on farmers of Haryana in India shows that a water tariff of 0.2 INR/ cubic meter will force the rice farmer's (<1 hectare) income to the bare minimum for the survival i.e. 5000 INR/year (approximately 100 Euros). As the small farmers are dominating in the Indian agricultural structure, the social and political cost of water price hike can be substantial (Alary and Deybe, 2005). But also the alternative, irrigation fee per unit area, creates no incentive to save water. It is primarily due to the fact that the farmer faces the same water price independent of his/her water use or his marginal cost of using water falls to zero. When the water use is not metered, the water actually used by individual farmer is private information which is not available for the regulating authority. This information asymmetry is a factor that makes the flat rate per unit area water pricing inefficient compared to volumetric pricing (Tsur, 2000).

3.5.2.2 Water price and cost recovery of irrigation services

The current average cost recovery of operating expenses from irrigation systems in Karnataka and Tamil Nadu is less than 5 % (Thakkar, 1999 and Mithra, 1997), far from 94.65 % in Karnataka and 22.5 % in Tamil Nadu during 1974-75. In converse, the national average investment cost to irrigate a hectare of area increased from 1200 INR in first five year plan period (1951-56) to 35081 INR in seventh annual plan period (1985-90) in nominal terms. But serious practical and political problems are driving Governments away from charging the water at its opportunity costs. Further, agricultural land prices embodies the water rights and if the water is charged at opportunity costs, the price of irrigated land may fall to the price of unirrigated lands which may seriously expropriate farmer's assets. The magnitude of such asset devaluations and social disruptions and unrest it causes makes the use of opportunity cost pricing far from pragmatic (Thobani, 1997). Nevertheless, the existing water charges which charged on a per hectare basis are not meeting the operation and maintenance of the large surface irrigation systems. Namoodiri *et.al* (2006) reports that the existing water prices ranges between 2.77 to 61.73 INR per hectare in Tamil Nadu and 37.05 to 988.45 INR in Karnataka. Tamil Nadu has not revised its water rates since 1962 while Karnataka has revised the water rates in 2000.

When considering the fact that the revenue collected through water charges contributes less than 5 per cent of the total operation and maintenance costs of irrigation projects in the study area, one has to deduce more reasons than the

prevailing low water charges. Various channels of *moral hazard* in the existing irrigation and revenue collection institutions can be another reason for lower revenue recovery. In the states of Tamil Nadu, Karnataka and Andhra Pradesh, the water charges are collected along with land tax i.e. through a higher assessment of land tax on irrigated lands. This creates a situation of Irrigation Department delivering water services and the Revenue Department collecting water fee (Saleth, 1996 in Mithra, 1997). The incomplete information of the Revenue Department on irrigated land area and the crop cultivated each year forms ways to opportunistic behaviour of local revenue collection officers. Many a time, local revenue officials report considerably less area under irrigation than the actual irrigated area and reroute the tax revenue to personal accounts but the information asymmetry protects the local officers from being responsible for revenue collection shortfalls (Huppert, 2005 and Samal and Kolanu, 2004).

Another feature of the irrigation system is that they are not demand scheduled, which means the supplies are less reliable from a farmer perspective. Also supply schedules are not made in consultation with farmers or farmer organisations in most of the irrigation systems though exceptions exist. Moore (1989) puts the reason of absence of demand scheduling to be the interaction between uncertain supplies from irrigation sources and inefficient information gathering and system management of the water managers. The information asymmetry on supply schedules gives way to opportunistic behaviour by irrigation managers, such as allocating more water to influential farmers or farmer groups in return of monetary and non-monetary benefits (Huppert, 2005). Many a time, deliberate uncertainty of supply schedules are introduced in order to elicit bribes i.e. the exhibition of rent seeking behaviour is observed (Repetto, 1986). Frequently farmers protest to the lack of quality of service by non payment of water fee but due to dichotomy of delivery of services (through irrigation department) and water fee collection (through revenue department) such protests are not effective. The financial allocation to irrigation department and incentives to irrigation officials are not linked with the system performance or revenue recovery, which further gives way to low quality service and opportunistic behaviour (Huppert, 2005). A vicious cycle of poor performance of Indian irrigation system is given below (adapted from Selvarajan, 2001).

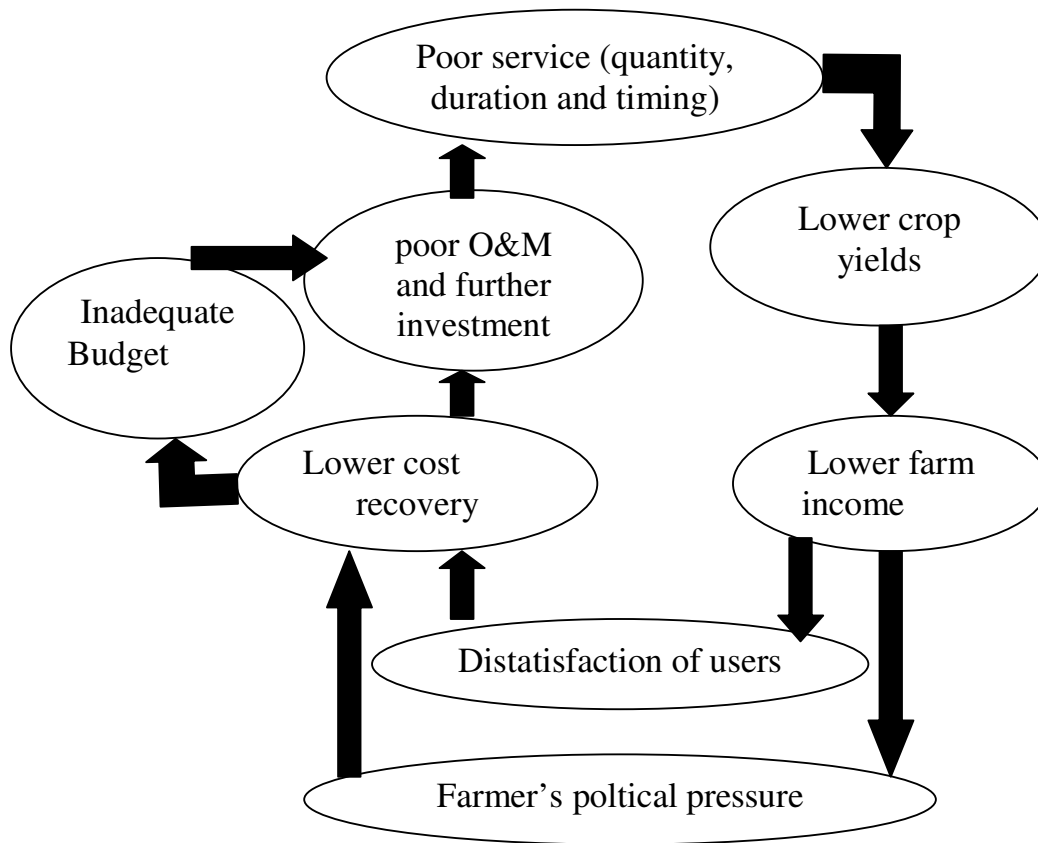


Figure 3.1: vicious cycle of poor performance of Indian irrigation system
Source: Selvarajan, 2001

Recently, formation of financially autonomous irrigation institutions is at the focus of governments in order to mobilize funds for the irrigation systems and to reduce the operating cost - revenue recovery gap. The aim of mobilizing funds to overcome the reduced budgetary allocations to irrigation sector is accomplished by public issue of bonds of these financially autonomous irrigation institutions. An example of such institutions is Karnataka's Krishna Bhagya Jal Nigam Limited (KBJNL). The bonds issued by the public limited company are backed by Karnataka state Government at an annualised yield ranged between 14.76 to 19.0 percent in various issues. The KBJNL was able to raise 46 billion INR by 2001. The money raised has been utilised for building irrigation infrastructure in Krishna River basin (Upper Krishna project area). Though KBJNL was successful in mobilizing the capital, the cost recovery of the irrigation investment is the real challenge in front of it. The committee on irrigation water pricing in India has suggested cost recovery should be aimed at covering operation and maintenance costs and attaining 1 percent interest of the capital invested. According to this strategy, the water price per hectare in KBGNL command was worked out to be

962 INR while the existing water fees in the area ranged from 37.5 to 100 INR. This means a ten to fifteen fold increase in water charges. The Karnataka government agreed to progressively increase the irrigation rates from the existing to the suggested rate.

When farmers came to know about the hefty water fees, political movements by farmer organisations thwarted the move to increase the water fee and were successful to retain the older rates due to their political lobbying power. This resulted in cost recovery figures that are far from actual operation and maintenance expenses. The main innovative feature of KGBNL is the wholesaling of water to farmer societies (WUAs) at a volumetric basis. Farmer's societies are responsible for collecting water charges from the members. It is also visualised that any reduction in water use by farmers may result in lower costs to farmer society and hence encourage water saving. This could not be realised in the absence of volumetric measurement of water to individual farmers (Raju *et al.*, 2003).

The world Bank summarised the factors that leads to low cost recovery in irrigation projects in Asia as: 1) absence of linkage between funds allocated for irrigation and revenue collected by it, 2) lack of participation by farmers in management of the irrigation system, 3) lack of communication between irrigation management and farmers, 4) low quality of service (in quantity, duration and timing of irrigation water delivery), 5) absence of performance linked incentives/disincentives in the irrigation management, 6) absence of penalties to users faltering in payment, 7) low priority given to operation and maintenance, fee collection and efficient water use, 8) small size and low income of irrigated farms and 9) corruption among irrigation officials (Easter and Liu, 2005). Nevertheless, there are justifications for partial payment of irrigation cost in India from public tax revenue. Study by Bhattarai *et al.* (2006) reveals that the irrigation multiplier operating in India is in the order of 3 to 4.5 which means around 30 percent of annual benefit from Irrigation falls into farmer's hand while 70 percent spills over to the rest of economy. Even then, the question of efficient utilisation of available resources and financial sustainability of irrigation institutions remain.

3.5.2.3 Water rights allocation in Indian irrigation systems

The existing practices on surface water allocation among users in India can be grouped into five viz. 1)Warabandi, 2)Shejpali, 3)Land class, 4)Satta and 5)Phad systems. In the Warabandi system, users are entitled to a fraction of total water flow available in proportion to land area while in the Shejpali system, delivery of a specific quantity of water under a given schedule to facilitate the crop to

maturity is practiced. In the Land class system, the class of the land i.e. single cropped, double cropped etc are considered along with the land area to decide water allocation. In the Satta system, the government agencies are responsible to provide an assured irrigation till the crop maturity. The Warabandi system is practiced mainly in North-Western India while the Shejpali system is predominantly used in western India, and the Land class system dominates in southern India. Finally, the Satta system is confined to north-eastern parts of India. In all the four systems mentioned, government agencies are responsible for the water allocation while in the Phad system practiced in small scale irrigation facilities in Maharashtra, local communities are responsible in water distribution (Namboodiri *et al.*, 2006).

3.6 Previous study in Cauvery Basin on water allocation

Vedula (1985) attempted an optimization model for a determination of optimum cropping pattern that will result in maximum net benefit for the farmers in the basin. This work also attempts to find a cropping pattern that can create maximum irrigated areas in the basin. He has verified the effect of upstream developments, i.e. construction of Yagachi, Harangi, Voteholes, Lakshmanathirtha, Chicklihole reservoir projects that would reduce annual inflow to Krishna Raja Sagar and Hemavathi reservoirs by 19.7% and 5.7% respectively. It is a twelve months irrigation model for the reservoir systems in the upper Cauvery basin. The inputs for the deterministic model consist of mean monthly flows into reservoirs, estimated monthly evaporation rate and mean monthly diversion requirements for irrigation. A maximization of net benefit by optimizing cropping patterns, given the constraints on land area, reservoir storage continuity, storage capacity and downstream release requirements, is carried out. Interestingly, inflows to Mettur reservoir are taken into account and downstream releases of water in each month are specified as minimum releases to ensure adequate water supply for existing irrigation in the delta and non delta region below Mettur. Alternatively optimum cropping pattern on maximum diversions or maximum irrigated area in the upper basin, given the same constraints are also worked out. The results show that proposed upstream developments may not affect the net benefits of the existing irrigation system, given the optimized cropping pattern. The author states the caution that the optimum cropping pattern, realized by the model, may not be acceptable for farmers. As it is a planning model and the operation plan to achieve the suggested area coverage of crops has to be conducted separately if results has to match with reality.

3.7 Environmental externalities in absence of water allocation agreements

Water logging and salinisation are common problems of over irrigation in upstream (head end) areas which are known as twin menace of irrigated agriculture. This problem can be due to factors such as inadequate lining of canals, inadequate drainage and excessive irrigation. In India, primary cause of water logging and salinisation is the lack of economic incentives to conserve water and restrict over irrigation (Wichelns, 1999). This problem in turn arises from ill defined property rights and institutional structures facilitating optimal water use (Oster and Wichelns, 2003). Volumetric water pricing and water markets are the economic instruments widely recommended to tackle the externalities. The unit area water pricing system practiced in India does not provide any incentive for individual farmer to restrain from over irrigation while volumetric pricing in developed countries provide economic rationality to restrict use. Coming to water trading, allowing farmers to trade the water entitlements among them, negative externalities such as water logging and salinity can be managed. In presence of a trading opportunity, farm level efforts to convert deep percolation and surface run off to marketable surplus may reduce the burden on local water tables (Wichelns, 1999). Saleth describes an 'incentive gap' that exists in India between value generated by current water use and the scarcity value of water and advocates policy reforms to close the gap. According to him, the incentive gap is resulting in practices that lead to water logging, salinisation and aquifer depletion in various parts of canal regions (Wichelns, 1999). Shankar *et.al* (2003) show that the cost of cultivation of Paddy in water logged areas of Kabini command in Cauvery basin is 7 percent higher than the normal farming areas in the basin while output was 34 percent lower than normal, resulting in a net loss of 12466 INR per hectare. In a similar study in Haryana shows that 10-12 percent reduction in yield in water logged areas that leads to 20-30 per cent loss in monetary terms when cost escalation in affected areas is accounted. In whole of Haryana, the estimated loss from these externalities is 1640 million Indian rupees (Datta and Jong, 2002).

Next, it can be seen that the access and management of surface water resources is intertwined with groundwater resource as the irregularities in the former often lead to over extraction and hence depletion of latter (Winter *et al.*, 2005). In the absence of well defined property rights, some farmers may use water quite inefficiently while other farmers are prone to frequent dry spells (Flatters and Horbulyk, 1995). In Cauvery basin, the competition between states on using available water has created water scarcity for agriculture (Tuong and Bouman, 2003). In order to save their crops, farmers in the basin switch over to the

extraction of ground water as an alternative. This is prominent in Cauvery basin as the main crop, paddy, is sensitive to water scarcity. As there are no incentives for long term optimisation of ground water use for individual farmer, excessive pumping from aquifers exceeding the recharge rate may occur. The resulting depletion, often expressed by falling ground water levels causes an increase in the extraction costs, deterioration in land quality and diminishing of land rents (Konikow and Kendy, 2005). The absence of legal and institutional mechanisms in managing ground water pumping and practical difficulties in monitoring individual ground water use leads to over-exploitation of ground water resource (Rosegrant and Biswanger, 1994). It is estimated that average fall in ground water level is 0.5- 0.7 meter per year in Karnataka and 1 meter per year in Tamil Nadu (Bouman and Tuong, 2003). The Centre for water policy (CWP, 2005) has reported that the districts in Karnataka and Tamil Nadu register a fall in ground water level more than 4 meters in every 20 years or 2 meter fall in ground water level in every 10 years. This includes Hassan, Mandya, Mysore and Tumkur districts in Karnataka and Tanjore, Tiruvarur and Trichy districts in Tamil Nadu that are in the Cauvery basin area. Tamil Nadu has 103 administrative blocks classified under over exploited category out of 384 blocks in 1998 (CWP, 2005). In Karnataka, the 56 per cent (1109 out of 1895) of observation wells by the department of mines and geology showed a decline in 2002 (ENVIS, 2007).

A fall in ground water levels due to over exploitation causes increasing cost of pumping, land subsidence and in some regions it results in sea water intrusion. Shah *et al.* (2003) identifies four distinct stages in groundwater based irrigation regimes in South Asia. The first stage is characterised by the traditional water lifting devices and concentrated rural poverty while the second stage is of groundwater based agrarian boom. In the second stage tube-well based irrigation creates rapid increases in rural income and employment. In the third stage, early symptoms of ground water over draft are visible as local water tables sink but the agrarian economy continues booming. In the fourth stage, the ground water bubble bursts and serious problems of ground water quality and quantity sets in. Shah *et al.* classifies central Tamil Nadu in third stage and coastal Tamil Nadu in fourth stage of ground water socio-ecology.

In summary, the literature reveals the pressing need for devising mechanisms that will result in efficient and equitable water allocation and reduction of externalities with in the legal, institutional, geographic and social conditions existing in the research area.

4. POLITICS AND ECONOMY OF NON-COOPERATION IN CAUVERY WATER SHARING

This introductory chapter (Chapter 1) discussed several details of the historical development of Cauvery river water sharing problem. In the current chapter we will discuss an important research question raised in Chapter 1 i.e. why the major riparian states did not cooperate in settling their initial water rights, even after elected governments replaced the kingdoms of asymmetric power.

4.1 Water and politics in Cauvery basin

The provision of irrigation water to farms ensures higher productivity of crops apart from reducing uncertainty in depending stochastic rainfall as the primary source of water for crops. In other words, irrigation provision insures farmers from potential crop failures due to uncertain weather conditions and enhances their incomes and living standards. This is evident from the Figure 4.1 which depicts the gap between mean irrigated and rainfed crop productivity in Karnataka. The gap ranges from approximately 1 tonne per hectare, in case of paddy and sorghum, to 0.75 tonne in case of finger millet, and 0.5 tonnes in case of groundnut.

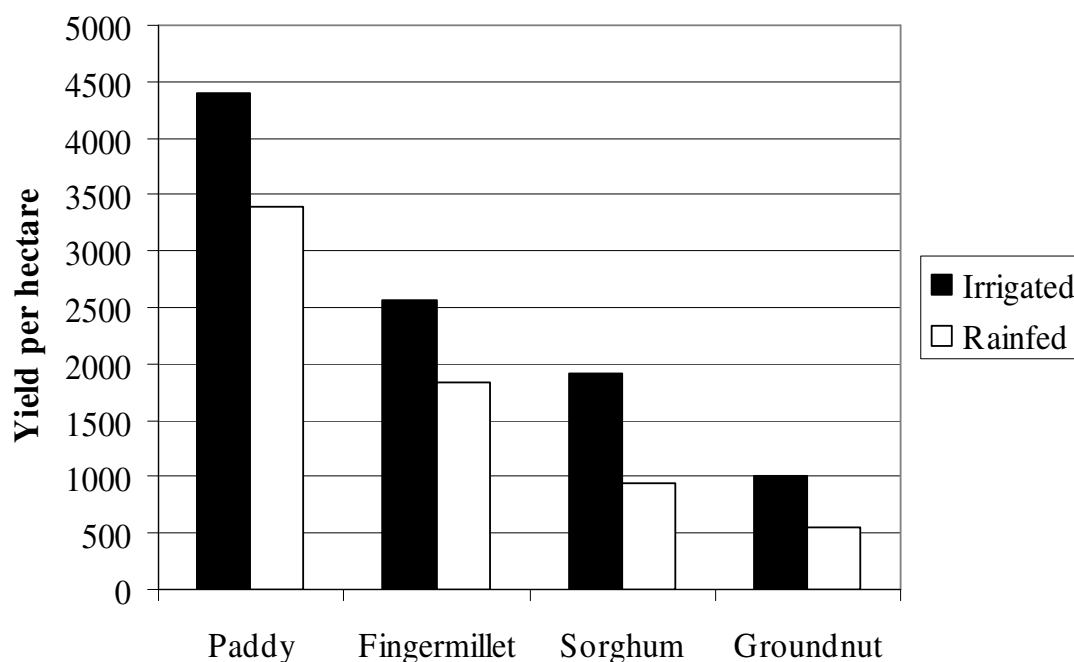


Figure 4.1: Mean productivity of important crops in irrigated and rainfed tracts of Karnataka

Source: Compiled from Directorate of Economics and Statistics (Karnataka), 2007

Being a key resource for millions of farmers in the Cauvery basin, water played and still plays a deciding role in the political landscape of the Cauvery basin. During the period Chola dynasty of 1st and 2nd century AD, provision of irrigation in Cauvery delta area by the construction of a water diversion structure, lead to a surge in agricultural revenue and ensured the dominance of the dynasty (Weber, 2005). Later during British colonial periods, enhancement of irrigation in Cauvery delta by constructing diversion structures and canals substantially increased the tax revenues for the Government. The economic benefit even made the Madras presidency to guard its water rights by including provisions in water sharing agreements with Mysore (detailed in chapter 1). The water - economy - politics linkage continues in Cauvery river basin and can be used to explain the non-cooperative stand point of democratically elected governments in the basin.

4.1.1 Karnataka scenario

Anand (2004) discusses the importance of the Cauvery River water sharing issue in winning *electoral constituencies in Cauvery basin* (ECCB) and in gaining majority in state legislative assemblies and in the formation of governments in Karnataka and Tamil Nadu. He links this strategic importance of ECCB to regional political parties' stand points in Cauvery water sharing. He stresses that the higher representation of ECCB in Governments of 1996 and 2001 (see figure 4.2) as well as the fact that 1/4th of members (56 out of 224) in state legislative assembly represented the ECCB indicate the importance of a populist political stand on Cauvery water sharing. The figures on local assembly results (Anand, 2004) indicate that, given the strong competition between parties in winning the electoral constituencies in Cauvery basin, policy on Cauvery water sharing can be a crucial factor in deciding the assembly election verdict in these constituencies.

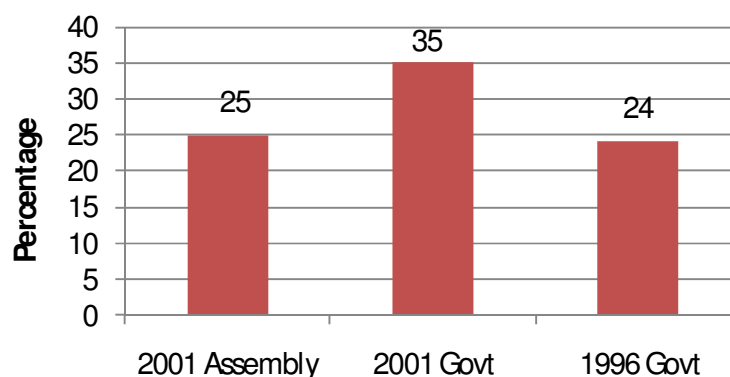


Figure 4.2: Representation of Cauvery basin constituencies in Assembly and Government of Karnataka Source: Compiled from Anand (2004)

Even though the electoral trends indicate the importance of ECCB in winning a majority in the state assembly and in the formation of government, there is a need of further evidence for proving the relation between voting pattern and political stand point of parties on Cauvery water sharing issues. To accomplish this objective, a question on voting behavior has been included the primary survey which covered four of seven basin districts in Karnataka. The farmers interviewed in the survey were confronted with the question of whether they will vote for a political party (Party A) which agrees to share water with Tamil Nadu irrespective of their current political affiliation. The results show that voting to opposition party (Party B) is a quite likely outcome. The graphical representation of the hypothetical voting scenario is given in the figure 4.3.

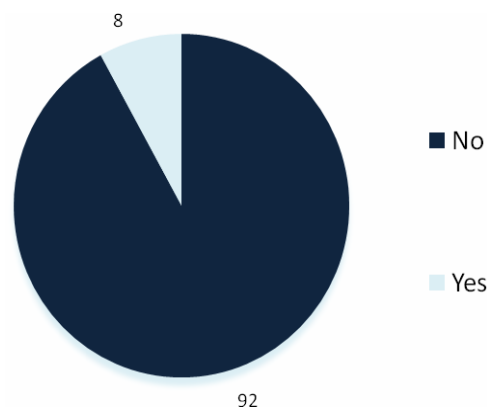


Figure 4.3: Share of voters in the sampled districts in Karnataka that may vote to Party A if it decides to compromise on sharing Cauvery water

4.1.2 Tamil Nadu scenario

The strong relationship of Cauvery water issues and politics is visible in Tamil Nadu as well. The importance of ECCB for assembly and Government formation is evident from available data (Anand, 2004). The figure 4.4 represents the share of ECCB in assembly and government formation. It can be seen that the share of ECCB in the government has increased to 32 percent in 2001 compared to 28 percent in 1996.

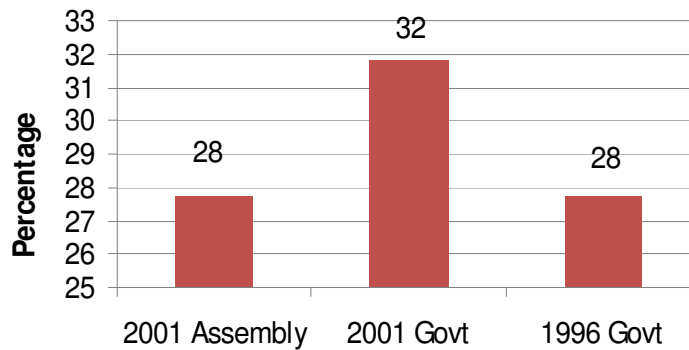


Figure 4.4: Representation of Cauvery basin constituencies in Assembly and Government of Tamil Nadu

Source: Compiled from Anand (2004)

As these electoral trends are not conclusive evidence for association between voting behaviour and political stand points of parties on Cauvery water sharing, we have included the question on voting behavior in the primary survey in selected districts of Tamil Nadu, also. The question confronted by the sampled farmers is whether they will vote to a party C, who compromises on water share with Karnataka, irrespective of their current party affiliation? Results show that Party C will be voted out as 70 per cent of the voters may decide against them (See figure 4.5).

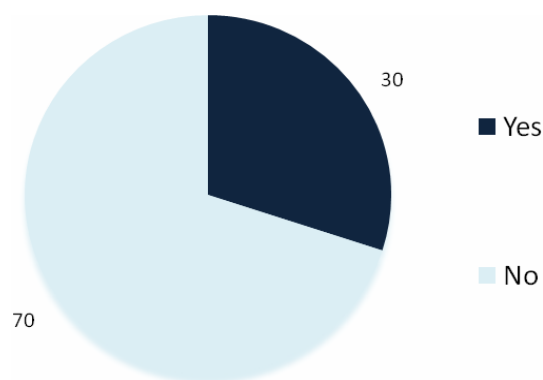


Figure 4.5: Share of voters that may vote to Party C, if it decides to compromise on sharing Cauvery water

The observed shifts in voting pattern in both states calls for further explanation on the voting behaviour in case of water issues and its role in the formation of political stand points; and it is dealt in the subsequent section.

4.2 A theoretical explanation of non-cooperative behaviour of basin states

Let us assume that the political positions of parties can be expressed as points in an ‘n’ dimensional Euclidean policy space. This follows Ansolabehere and Snyder (2000). The ideal position of a voter (farmer in our case) can also be expressed as a point in this policy space. The difference in distances from ideal position to party policy stand points (which is a difference in utility) determines voter’s choice; i.e. she will vote for the party closest to her ideal position in the policy space. The graphical depiction of this policy space is given in figure 4.6 with economic, environmental and social policy dimensions as examples. Let us denote the policy position of a party by the point, X i.e. X^A is the policy stand point of Party A and X^B is the policy position of Party B. Z is the ideal position a voter in the policy space.

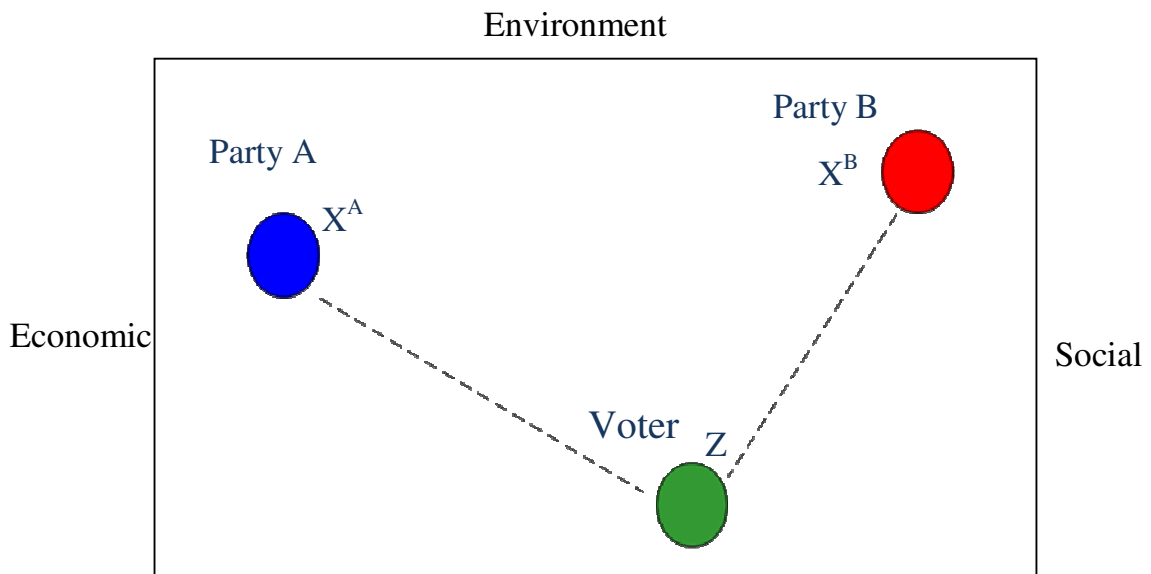


Figure 4.6 : Depiction of position of Party A, Party B and voter in n- dimensional Euclidean policy space.

Let $\| X^A - Z \|^2$ be a distance, which is the absolute value of distance from the party A’s policy position (X^A) to voter’s ideal policy position (Z). It represents the utility of the voter by voting to the party A i.e. $U(X^A, Z)$. Similarly, let $\| X^B - Z \|^2$ represent the utility of the voter by voting to the party B i.e. $U(X^B, Z)$. The Outcome of the electoral competition, between Party A and B in this case, is determined by the difference in $U(X^A, Z)$ and $U(X^B, Z)$. Let us take our real life electoral competition in Karnataka and Tamil Nadu. They are usually a two party or two coalitions competition. The major parties in Tamil Nadu are DMK and AIDMK while Janatha Dal (JD) and Congress are leading parties in Karnataka. Though the last election witnessed Bharathiya Janatha Party (BJP) coalescing

with JD to form the government. For theoretical examination, we can consider them as Party A and B in Karnataka and Party C and D in Tamil Nadu. So the electoral outcome is decided by the difference between the distance between policy stand points X^A and X^B in the case of Karnataka ($\Delta U(X^A, X^B, Z)$) and is formalized by the equation (Following Ansolabehere and Snyder, 2000),

$$\Delta U(X^A, X^B, Z) = \| X^A - Z \|^2 - \| X^B - Z \|^2 \dots\dots\dots (1)$$

If $\Delta U(X^A, X^B, Z)$ which represents the utility difference between Party A and B in the equation is less than zero, it means that the distance from voter’s ideal position to the party A is less than corresponding distance to the party B. In other words, party A is closer to the voter’s ideal position. This ensures the Part A being the winner. If $\Delta U(X^A, X^B, Z)$ is greater than zero, Party B will be the winner. If it is zero there is tie.

In our simplistic representation of elections, we can incorporate issues of very high influence on voting pattern as decisive variables. Ansolabehere and Snyder (2000) call such issues as valance issues. It is incorporated as a score Y with a weighting factor λ . The Y depends on the party stand on the valance issue and the weighting factor λ , which represents the power of the valance issue in deciding the electoral outcome. The higher Y denotes, the more acceptable is the stand on the valance issue by a party; while a high λ shows it ability to influence voting decisions. In presence of such important issues, utility gained by voting to party A can be represented (Following Ansolabehere and Snyder, 2000) as

$$U(X^A, Y^A; Z) = \lambda Y^A - \| X^A - Z \|^2 \dots\dots\dots ..(2)$$

Here the score on party policy on the valance issue for the party A is Y^A .

Similarly, utility gained by the voter voting to party B is

$$U(X^B, Y; Z) = \lambda Y^B - \| X^B - Z \|^2 \dots\dots\dots (3)$$

The electoral outcome in equation 1 can be reframed as

$$\Delta U(X^A, Y^A, X^B, Y^B; Z) = [\lambda Y^A - \| X^A - Z \|^2] - [\lambda Y^B - \| X^B - Z \|^2] \dots\dots(4)$$

By rearranging (4),

$$\Delta U(X^A, Y^A, X^B, Y^B; Z) = \lambda(Y^A - Y^B) + \| X^B - Z \|^2 - \| X^A - Z \|^2 \dots\dots\dots(5)$$

This equation points out that the electoral outcome will be depending on the difference in distance between the policy stand points of Party A and B as well as

their stand point in valance issue. If $\Delta U(X^A, Y^A, X^B, Y^B; Z)$ in the equation 5 is greater than zero, voter gets more utility by voting to party A. This ensures the Part A being the winner. This can happen if the party A is closer to the voter’s ideal policy stand point and if its stand point in critical issue (valance issue) is a popular one. If $\Delta U(X^A, Y^A, X^B, Y^B; Z)$ is less than zero, Party B will be the winner. This means the party B is the closest to the voter’s ideal policy stand point and if its stand point in critical issue (valance issue) is the popular one. If it is zero there is tie. The same case is applicable for the parties C and D in Tamil Nadu. Let us denote the outcomes i.e. Party A being winner, Party B being winner and both parties tie to be 1, -1 and 0.

Let us consider the Cauvery water issue as a valance issue. The swing voting patterns are evident from in the primary survey conducted in Karnataka and Tamil Nadu. They show the high power (λ) of this valance issue in deciding the voting behaviour and hence deciding the electoral outcome of Cauvery Basin districts. The data presented in section 4.1 shows that wining in these electoral constituencies in Cauvery Basin is decisive in government formation. In this scenario, let us examine the combinations of strategies that parties can take in Karnataka (A or B) and Party in Tamil Nadu (C or D) on Cauvery water sharing. The prisoner’s dilemma on strategy choice is presented in table 1.

Table 4.1: Prisoner’s dilemma in water sharing

		Party B	
		Strategy	Cooperate in sharing water
Party A	Cooperate to sharing water	$\ X^A - Z \ ^2 - \ X^B - Z \ ^2$ (Outcome can be 1, 0 or -1)	$\lambda(Y^A - Y^B) + \ X^B - Z \ ^2 - \ X^A - Z \ ^2$ (Outcome is -1 or party B wins)
	Non-cooperate to sharing water	$\lambda(Y^A - Y^B) + \ X^B - Z \ ^2 - \ X^A - Z \ ^2$ (Outcome is 1 or party A wins)	$\ X^A - Z \ ^2 - \ X^B - Z \ ^2$ (Outcome can be 1, 0 or -1)

In the scenario of high ability of the valance issue (Cauvery water sharing) in swinging votes, taking the populist stand on the valance issue can make sure that the election outcomes depend only on the policy positions of Party A and B (X^A and X^B). If a party A takes the populist point on the valance issue i.e. noncooperation in sharing water, it makes sure that it has a fair chance to win the election independent of the Party B stand on the valance issue (see table 4.1). It means that the Party A strategy to take the populist stand point of noncooperation ($Y^A=1$) leaves two options for party B i.e. to assume the same stand point ($Y^B =1$)

or to cooperate in water sharing ($Y^B=0$). If the party B takes the latter position in the valance issue, Party A will be the winner irrespective of Party B policy position and if the Party B takes the same position as of A i.e. to non-cooperate, Party A gets a fair chance to win electoral competition depending on its distance from the ideal policy point of the voter. It is the same case with Party B. This condition forces the parties to take the same strategy on the valance issue which is the noncooperation in water sharing.

In the presence of the prisoner's dilemma, an optimal strategy of the Party A and B as well as the governments formed by them is to non-cooperate on Cauvery water sharing as that this strategy gives best possible outcome irrespective of the other party stand. If we superimpose the same strategy options for Party C and D in Tamil Nadu, the same outcome, i.e. refusal to make compromises on Cauvery water sharing, will occur from both sides. This is precisely so as the sets of parties contesting in both states are mutually exclusive. In conclusion, irrespective of the fact that Party A or B is in power in Karnataka, Party C or D is power in Tamil Nadu, compromises may not occur at bilateral level unless the Cauvery water share tones down in its political importance ($\lambda \rightarrow 0$).

4.3 Political importance (λ) and the underlying economic motives

The current conflict is based on the physical sharing of initial river water rights and not on sharing the net benefits that the water represents. Nevertheless, the farmers' (voters of the party) political reaction is based on economic considerations. As the water in the Cauvery River is fully allocated with out any surplus (see chapter 1 and 2), any reallocation will cause water allocation to be less than benchmark water receipts in both Karnataka and Tamil Nadu. The benchmark in Karnataka is the current level of utilization of Cauvery waters and in the case of Tamil Nadu, it is the historical water receipts stipulated in 1824 agreement. Assuming farmers' income is a linear function of water received, any reallocation will reduce the economic welfare of farmers compared to the benchmarks. In addition, in the absence of flexibility in water allocation mechanisms, the initial water rights allocations represent the maximum income that farmers can gain from cultivating the irrigated crops at current technology. This economic consideration is expressed in voting behaviour as evident from the surveys conducted in sampled districts.

For a comparison, the primary survey also included a question on voting behaviour with respect to a party offer of providing electricity free of cost for pumping ground water for irrigation. This policy already exists in Tamil Nadu though number of free connections is limited. When posed the question in the

primary survey in Karnataka i.e. whether the respondents will vote for a political party offering free electricity to farmers (irrespective of their current party affiliation) showed a 50 percent swing in votes. The major reason for not shifting the voting (for the other half of respondents) is that the respondents viewed it as an election gimmick and expressed doubt on the credibility of such an offer. Nevertheless this exercise shows how economic considerations in irrigation water access get expressed into voting behaviour in the research area.

From the political prisoners' dilemma depicted in table 4.1, it is clear that the political importance (λ) should fall considerably for evoking a cooperative behaviour. This can happen in presence of a mutually beneficial sharing scheme or in other words, an arrangement where net gain from cooperation is positive for both states. In the coming chapters, a water trading mechanism i.e. an exchange of water for money among the water user groups is examined for its potential to reduce the welfare loss due to cooperation and hence its political importance.

5. WATER RIGHTS MARKET AS A MECHANISM TO RECONCILIATE THE WATER SHARING DISPUTE

As stated in the previous chapter, the Cauvery water sharing dispute is currently a dispute over quantity of initial river water rights and not of the net benefits that the water represents. Nevertheless, the political importance is footed on the farmers' economic benefit from the water allocated to each of them. As the water rights and its usage can become independent in presence of a water rights trading mechanism (Fisher, 1995), defining water rights and establishing a system of trading these water rights is required to address the water sharing as an issue of sharing the economic benefits. This approach keeps the focus on economic value of water rather than quantity allocation and hence it does not matter who holds the right but rather who gets the money that the water represents.

5.1 Water rights market in a developing country: challenges and opportunities

Rosegrant and Binswanger (1994) suggested a set of advantages of allowing a functional market to decide the allocation of water among competing users and sectors. They compared the water market with other instruments. The main arguments that they have put forward on supporting water trade in comparison to other modes of water allocation are (1) the rapidly increasing scarcity of water, (2) its high value on reallocation, (3) sizable transaction costs of alternatives like administrative and community management, (4) political constraints of opportunity cost pricing, (5) possibility of reductions in externalities by the water trading, and finally (6) the possibility of investment mobilization by water users. The major bottleneck in applying a market based approach in developing countries, according to them, is the presence of (1) the high transaction cost of establishing the prerequisites of a functional water market i.e. assignment of the initial water rights and the provision to physically regulate the water flow to individual fields, (2) the high transaction costs of finding a suitable and willing buyer for the individual water rights and (3) the associated administrative costs of reassigning the water entitlements. Considering the small size of individual farm holdings (less than 2 hectares) in most irrigation systems of developing countries, these costs make the market based instruments in water allocation an unviable proposition. Hence the reduction of establishment and transaction costs is the greatest challenge in front of the policy researchers who are designing better market based water allocation instruments in developing countries (Msangi *et al.*, 2006). Otherwise, the existing mode of centralised water allocation becomes the economically viable alternative, though it is far less efficient in water management.

Rosegrant and Binswanger (1994) mentioned that a possible way to reduce the establishment and transaction costs in the water rights markets of developing countries is assigning property rights to water to user communities instead of individual farmers. This argument is pointing towards downsizing the number of players in the water market and hence substantially reducing the stated costs. A similar argument is presented by Msangi *et. al* (2006). But the major question to be answered is how a group of farmers can be coordinated to act as a single player in a water rights market so that rights can be traded among water user communities instead of individual small sized farmers? The authors did not try to elaborate on this aspect. The current chapter attempts to portray a coordination mechanism that can act as a visible hand by synchronising the individual farmer actions in water user communities and hence facilitating the invisible hand of water market in water reallocation among the communities.

5.1.1 Property rights: community and individual

In the case of a resource like water, its allocation when property rights are ill defined is obviously challenging (Ambec and Sprumont, 2002). Property rights over any asset, in general, encompass the right to use the resource, realise income, sell, or exclude others. An associated concept is the transaction cost which is defined as the cost of protecting and exchanging property rights (Holden and Thobani, 1996). It is self-evident that allocating water rights to each miniscule farm holdings in a large river basin can be quite high, as it means quantitative allocation and monitoring of water use of each individual farmer plots. In addition to metering of water, monitoring the proper functioning of water meters against tampering and malicious practices can make it even more expensive in practice. Considering this fact, it can be argued that limiting the allocation of water rights and its quantitative physical allocation to water user association level (WUA) can substantially reduce the implementation and transaction costs. The initial allocation of rights can be based on historical water use of the WUA so that the political friction in assigning initial water rights can be minimized. However, the question is what will be the roles of individual farmers and the WUA, if they want to participate in the water market, this has to be clarified.

As stated in Chapter 3, some of the financially autonomous irrigation institutions in India, like the Krishna Bhagya Jal Nigam Limited (KGBNL) of Karnataka, are practicing the quantitative wholesaling of water to farmer societies. The KGBNL charges water prices according to the quantity used by the farmer societies and they are responsible for collecting the water charges from the individual members. It is also visualised that any reduction in water use by farmers may result in lower costs to a farmer society and hence may encourage water saving. Nevertheless,

this could not be realised in the absence of volumetric measurement of water at individual farmer levels (Raju *et al.*, 2003). It is evident from this case that, in the absence of volumetric measurement of individual water use, water user groups require a coordination mechanism that links the individual efforts to incentives. Such a mechanism can invoke a coordinated response to water prices.

5.1.2 Water trade and water saving

An individual farmer, holding a right to consume a specific amount of water and facing a water market, may employ water saving techniques in his/her field and sell the saved water to realise additional income (Dinar and Letey, 1991). Water saving practices can range from simple management methods to modern capital intensive techniques. The options in front of the farmer can even be changing over to rainfed cultivation so that the whole water right can be sold. This is economically rational only if the cost of transition to a water saving mode of cultivation is lower than the gain from selling the saved water. It is hereby argued that if water rights are allocated to the water user group, selling of a part of water right in exchange of money may not automatically result in the use of water saving techniques in the fields of the WUA members, as there is no explicit linkage between individual efforts to save water and individual gains. It means that the price signal given by the water market may not be able to guide actions at individual farmer level. In other words, the invisible hand of water market mechanism needs to be assisted by a visible hand or a coordination system at WUA level to make sure that the water market result in the desired outcome. A mechanism of coordination at WUA level to induce water saving at individual farmer fields is discussed in the following sections.

5.1.3 Water trade and agricultural production

Another important criticism of the use of market based approaches in developing countries is that the water trading may cause excessive reallocation of water to industrial purposes and domestic use and hence can cause significant reduction in agricultural production. Rosegrant and Binswanger (1994) argue that there is scope of efficiency gains in both agricultural and non-agricultural sectors if the buyers face full opportunity cost of tradable water but see chances of modest levels of water transfers from agriculture to non-agricultural sectors. Nevertheless, it may be desirable to restrict the access to the water market to those farmers who do not abandon cultivation. This explicit arrangement is required to make sure that the agricultural production is sustained in cultivable areas of developing countries, even in the presence of the water market. This condition may be important as food shortages and associated price raises are becoming common in these countries. We handle this issue by limiting water rights that can

be traded in the water rights market to aggregate water use reductions (or savings) achieved by employing water saving irrigation techniques or crop raising which are practiced by members of the water user community. This condition also means that crop cultivation becomes a prerequisite for participating in the water market and hence maximising the revenue from water trade becomes independent of crop cultivation per se.

5.2 The water market setting

We start the description of the water market by specifying the actors and their roles. Water user associations, water authorities and farmers are the main actors at both supply side and demand side of the water market. Non-agricultural users of water also can be a part of the demand side. We see a Water User Association (WUA) as a cooperative body which is responsible for irrigation water management in the area under its command and the Water Authority is an agency that manages water allocation over a large area (Eg: Irrigation departments in Karnataka and Tamil Nadu) which quantitatively allocates water to WUAs. Every farmer is assumed to be a member of the WUA. As the user associations hold water right according to the historical abstractions of surface water, quite a number of WUAs will have at least sufficient amounts of water for agriculture at current level of irrigation technology. We term them as WUA-(seller). These WUAs are at the supply side of the market while the remaining water user associations, facing deficit in surface water rights, are at the demand side along with non agricultural users. Let us call them WUA (buyer). We present a skeletal view of such a water market for the research area in the figure 5.1.

5.2.1 Conceptual frame of the interstate water market

Figure 5.1 shows the conceptual frame of an interstate water market in the Cauvery River Basin. Here the initial rights are allocated to Karnataka and Tamil Nadu by the Cauvery tribunal and the rights are further distributed by the water authorities among WUAs according to their historical water use. Both intra state and interstate water trade is allowed. The possibilities of the trade are 1) WUA in Karnataka sells the water right to a WUA in Tamil Nadu, 2) WUA in Karnataka sells the water right to another WUA in Karnataka, 3) WUA in Tamil Nadu sells the water right to another WUA in Tamil Nadu 4) WUA in Tamil Nadu sells the water right to another WUA in Karnataka. The arrows in the figure 5.1 indicate these possibilities. All the water trade is organized by the water authority in this conceptual framework. It also acts as a hub for exchanging the rights. The water trade is beneficial if the reallocation leads to a Pareto optimal increase in benefits compared to the status quo allocation in the river basin.

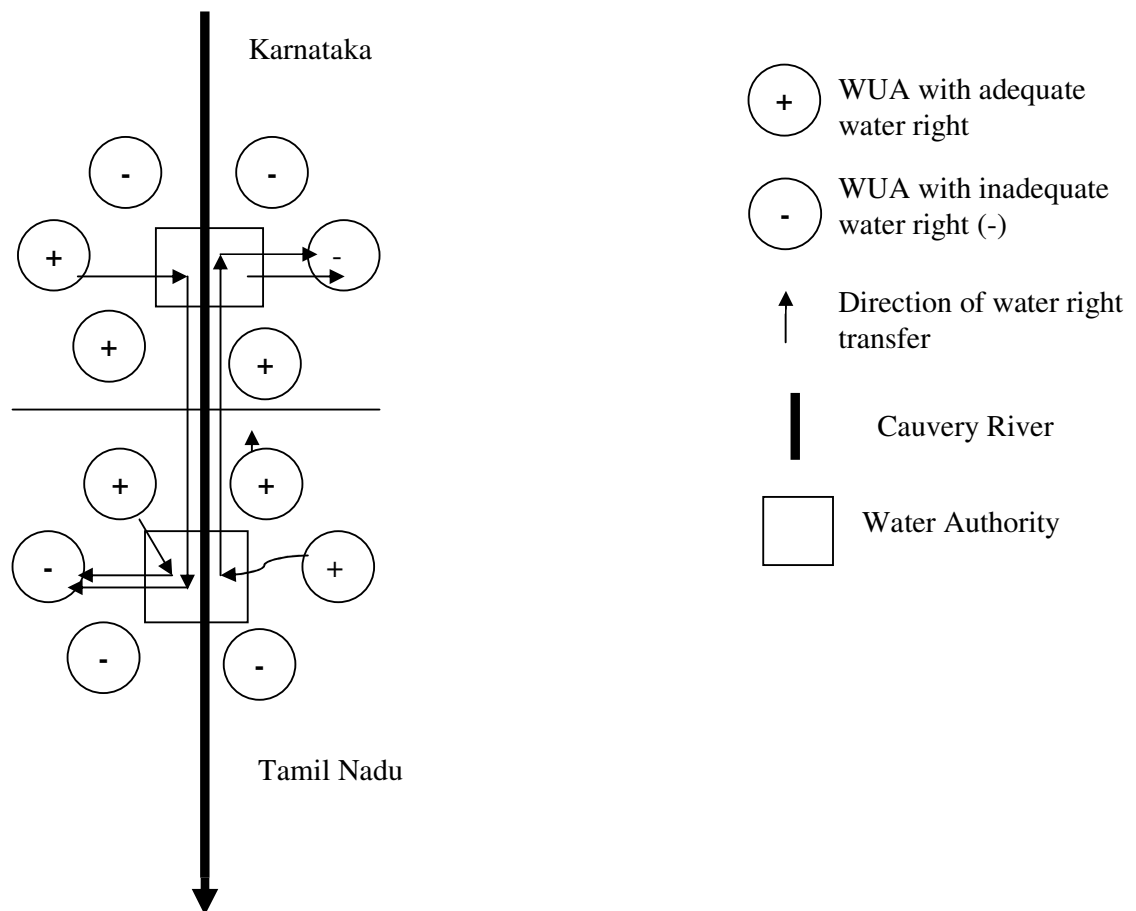


Figure 5.1: Water rights transaction possibilities in a water market set up in the research area.

5.2.2: The supply side of the water market

A detailed conceptual diagram of the supply side in this water market setting is furnished in figure 5.2. The water and money transfers in the proposed water market are indicated. As previously stated, a WUA at the supply side holds adequate water rights. These water user communities with sufficient rights can reduce the water demand by organising the water saving cultivation practices in farmlands under their command by coordinating the required actions of the member farmers. The surplus rights generated can be sold to a WUA at the demand side. The WUA (buyers) have to purchase water rights from the pool of rights offered by the supply side through the Water Authority. This setting of allowing purchases from common pool of water rights makes sure that transaction cost of searching and finding a buyer for the seller and a seller for the buyer can

be minimized and will make sure that prices will lead to efficient redistribution of water rights. As trade of water rights are closed before the physical transfer, cost of water reallocation can be reduced substantially. Water price formation takes place according to demand and supply conditions like in a normal market (similar to a commodity bourse) and it decides the money flow in the whole market system. Electronic markets like in the Westlands Irrigation District in California, are also perceivable (Landry and Anderson, 1999). The differences between a normal water right market and the proposed water market concept can be deduced from the conceptual diagram. The differences are that the buyers and sellers are water user communities instead of individuals and water rights are sold before the physical allocation of water. The remaining portion of the chapter is concentrating on the coordination of the individual farmer members in a water user association at supply side so that the group can act as an individual seller.

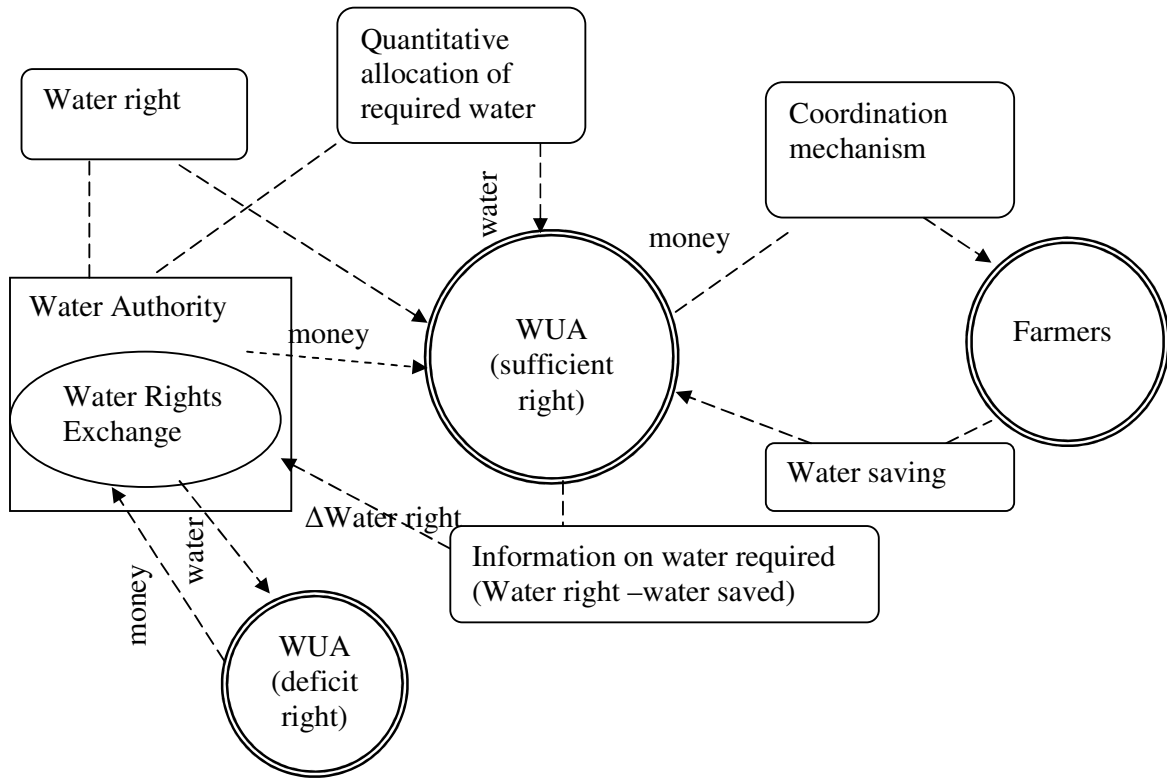


Figure 5.2: Skeletal view of the water market concept with the visible and invisible hands.

5.3 The visible hand

As a discussed already, a visible hand should coordinate actions of the individual farmer members to assist the invisible hand of market price of water in guiding farmer’s decisions in water saving and trading activities in each WUA. A revenue sharing contract between WUA and an individual farmer is the coordination

device proposed here. This contract is a mechanism to coordinate the water saving activities among its members by regulating the sharing of the revenue realised by water trading. We are adapting a principal-agent (P-A) model to derive the contract conditions so that WUA can maximize the surplus rights and hence the revenue for all of its members. The surplus rights are generated by the use of water saving techniques and the use of appropriate cultivation practices in individual farmer's fields. The cooperative nature of the WUA is given its due importance while framing the P-A model.

5.3.1 A principal-agent model of the contract scheme

Let us discuss the contractual relationship between WUA and the farmers. It has been already assumed that the water user association has sufficient water rights for crop cultivation at the current irrigation technology. The aim of the WUA is to maximize the water surplus that can be traded at a given price. In a normal water market where individuals hold the water rights, each of them can engage in water saving agricultural practices and sell the surplus water rights. As previously stated, only a clear specification of individual effort and individual gain relationship can bring the right level of individual activities when water rights are allocated to user groups. In order to frame such a relationship, the WUA is assumed to be a principal of a cooperative nature who is engaging in revenue sharing contracts with farmers in return of water saving practices in their individual fields. Farmers are agents working for the principal's goals in this setting.

The principal, WUA, is interested in maximizing the farming area under 'revenue sharing for water saving' contracts so that it can maximize the water surplus that can be traded and hence its revenue. As there are a number of WUAs who are at the supply side, we index them with a superscript 'i.' Recall that WUA^i holds the right to use certain amount of water (x^i) for irrigation which is sufficient enough under current cultivation and irrigation technology. WUA^i consists of n^i ($1\dots s\dots n^i$) number of farmers and the WUA management. As the contract scheme for a single WUA at the supply side is derived here, the superscript 'i' can be dropped for reducing notational complexity.

Let us discuss the principal-agent (P-A) relationship from the perspective of the agent or the farmer who is engaged in a crop raising enterprise. It is assumed that the use of water saving techniques or cultivation methods will not affect the agricultural output but will inflict a cost depending upon the area of its use by the farmer. This means that more the land area allocated to the water saving mode of cultivation, more is the cost inflicted and more is the water saved.

5.3.1.1 The cost of employing the water saving technique

The transition from traditional to water saving modes of irrigation is costly to farmer, for instance, in terms of additional labour or capital. A disproportional increase in costs for each additional unit of area under water saving practice can be visualised. For this we assume a linear marginal cost curve, which implies a quadratic cost function, $C(l_s)$

$$(1) C(l_s) = \varphi_s \cdot l_s + 0.5 l_s' \Psi_s l_s$$

Where φ_s and Ψ_s are the parameters of the cost function and l_s denotes the farming area under water saving irrigation / cultivation technique for the farmer, 's'. Note that land area allocation can be easily monitored unlike water use of each farm which substantially reduces the transaction costs of the WUA.

5.3.1.2 The 'revenue sharing for water saving' contract

In order to facilitate the transition to the water saving irrigation/cultivation from the traditional irrigation/cultivation in agent's fields, the principal (WUA) offers an revenue sharing scheme that has two components i.e. a fixed component to convince the risk averse farmers to employ the water saving practices and a variable component to ensure the effort of the agent farmer. Following Furubotn and Richter (2005), the incentive scheme is

$$(2) W(l_s) = r_s + \alpha_s P_w h_s l_s$$

where r_s denotes the fixed component of the linear incentive scheme in WUA which may be paid in advance. α_s stands for share of the s^{th} farmer from $P_w h_s l_s$ which is the revenue realised by the WUA from his/her effort. Here P_w is the unit price of water in the water market and h_s is the conversion factor that converts the land area under water saving irrigation/ cultivation (l_s) to water saved in quantitative terms (eg: cubic meter). h_s is assumed to be fixed for the water saving technique employed by the farmer 's'. The total water right sold by the WUA is equal to $\sum_s h_s l_s$ which is equivalent to $x - x'$ where x' is the water required in the whole WUA after the employment of water saving measures in farmers' fields and "x" is the quantity of water for which it holds the right.

5.3.3 Incentive constraint

The agent's (farmer's) gain depends upon the linear incentive that the WUA offers and the cost of transition to the new mode of irrigation or cultivation. The gain of the farmer can be represented as the surplus that he/she derives when

additional cost of water saving is deducted from the principal's incentives (equation (2) – equation (1)).

$$(3) W(l_s) - C(l_s) = r_s + \alpha_s P_w h_s l_s - \varphi_s l_s - 0.5 l_s' \Psi_s l_s$$

So, the agent farmer's aim is to maximise his gain, $W(l_s) - C(l_s)$. If we take the first derivative with respect to the variable 'land area' (l_s),

$$(4) \alpha_s p_w h_s - \varphi_s - \Psi_s l_s = 0$$

Rearranging (4), we receive a linear response function

$$(5) l_s = \Psi_s^{-1} p_w h_s \alpha_s - \Psi_s^{-1} \varphi_s$$

Equation (5) represents the agent's response function for the principal's payment scheme. It also can be called an incentive constraint as the principal can induce optimum level of farmers' land area by certain income share α_s .

5.3.1.3 Participation constraint

Participation of farmers is ensured when the additional benefit realized by engaging in a contract is at least equal to farmer's reservation utility (\bar{R}) (Furubotn and Richter, 2005). So, the additional income from the contractual arrangement has to be greater than or equal to his/her reservation utility.

$$(6) W(l_s) - C(l_s) = r_s + \alpha_s P_w h_s l_s - \varphi_s l_s - 0.5 l_s' \Psi_s l_s \geq \bar{R}$$

Taking \bar{R} as κ_s , which means a minimum gain per unit area (κ) is required to ensure participation,

$$(7) r_s + \alpha_s P_w h_s l_s - \varphi_s l_s - 0.5 l_s' \Psi_s l_s = \kappa_s$$

Rearranging (7), the participation constraint is

$$(8) r_s = \varphi_s l_s + 0.5 l_s' \Psi_s l_s - \alpha_s P_w h_s l_s + \kappa_s$$

5.3.1.4 Principal's objective function

The principal or the WUA is interested in maximising its income. Each WUA is assumed to be a price taker as the water price is determined by the market demand and supply conditions. Hence the total revenue of WUA ($P_w h_s \sum l_s$), depends on the total land area allocated to water saving mode of cultivation ($\sum l_s$) as h_s is a constant for a given water saving technology. So the WUA has to maximize the total land allocation to water saving mode of cultivation in order to realize

maximum revenue. The principal takes effort to convince the farmers to join the contract and its reward (PI) is modeled as

$$(9) \text{ PI} = \sum_s [(1 - \alpha_s)(P_w h_s l_s - r_s)] = (1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s$$

The share of net revenue (after paying the fixed component of the linear incentive scheme (r_s) that the principal gets from each agent is $(1 - \alpha_s)$. The objective is to maximize PI, given the incentive and participation constraints,

$$l_s = \Psi_s^{-1} p_w h_s \alpha_s - \Psi_s^{-1} \varphi_s \text{ (IC)}$$

$$r_s = \varphi_s l_s + 0.5 l_s \Psi_s l_s - \alpha_s P_w h_s l_s + \kappa l_s \text{ (PC)}$$

Nevertheless, in this setting, the principal tries to maximize rewards and lacks the character of a cooperative. Here the principal acts like a profit oriented private firm. In order to incorporate the characteristics of a cooperative, a bonus scheme is introduced.

5.3.1.5 The bonus scheme

Recall that the principal i.e. the WUA is a cooperative body. Hence the profit left after payment of a decent remuneration to the WUA members is shared among the agents (WUA members) as a bonus. The bonus can be represented as a share (β) of the profit from the water trade, (following Zusman, 1989) and the total bonus to the WUA members (B) can be represented as

$$(10) \text{ B} = (\beta) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$$

Note that $(1 - \beta) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$ goes to the principal and B represents the bonus amount that has to be distributed among the members. The β can take values from 1 to zero. The condition, $\beta = 0$ means that all the profit rests with the principal and no bonus is given to agents and $\beta = 1$ indicates that the whole profit of the principal is distributed among the agents. The desirable scenario is a value in between 1 and 0.

We can visualize two kinds of bonus sharing schemes i.e. equitable and equal types. Equitable bonuses are distributed according to the land area that each agent put under the water saving contract while equal bonuses are distributed according to head count of agents. If we resort to the equitable type of bonus, which gives more reason for large farmers to join the contract, the bonus to individual farmer will be

$$(11) B_s = \left(\frac{\beta l_s}{\sum_s l_s} \right) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$$

It is to be noted that B_s is an individual bonus received by the farmer ‘s’ and the sum of B_s over all farmers is B i.e. $B = \sum_s B_s$.

We can use the bonus scheme as a team incentive (Romstad, 2003) as well. A team incentive here is an incentive which stimulates farmers, engaged in the contract, to lobby other farmers to join the team at no cost to the principal (Collins and Maille, 2008). To make the bonus a team incentive, we add a correction factor (c.f) to the individual bonus function,

$$c.f = \frac{(\sum_s l_s)^2}{(A)^2}$$

The new individual bonus function after incorporating the correction factor is

$$(12) B_s = \left(\frac{\beta l_s \sum_s l_s}{A^2} \right) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$$

Here “A” is the total farm area under the water user association. The correction factor becomes unity when whole area comes under the contract ($\sum_s l_s = A$), which means a full bonus will only be realised when all farmers join the contract and bring all their land area under the ‘revenue sharing for water saving’ contract. As the correction factor is a squared term, an increase area under the contact scheme will result in more than proportional gain of bonus to all farmer members. For example: If whole farm area (A) is under the contract ($\sum_s l_s = A$), the farmers can realise 4 times the bonus compared to a scenario where the 50 percent of farm area ($\sum_s l_s = \frac{1}{2} A$) is under the scheme.

This incentive may force farmer (members) to lobby other members to join the contract at no cost to the principal. In addition, it may also encourage farmers to allocate their whole farm area to the contract and to lobby others to do the same

5.3.1.6 Updated incentive constraint

When bonus scheme is (added) included to the gain function of the farmer agent,

(13)

$$W(l_s) - C(l_s) = r_s + \alpha_s P_w h_s l_s + \frac{\beta l_s \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] - \varphi_s l_s - 0.5 l_s' \Psi_s l_s$$

As each agent is trying to maximise her gain, first derivative of (14) with respect to l_s is equated to zero

$$(14) \quad \alpha_s P_w h_s - \varphi_s - l_s \Psi_s + \frac{\beta \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] = 0$$

It is to be noted that we treat $\sum_s l_s$ as a variable which can not be influenced by the decision of a single farmer alone as each of them holds only a small fraction of the total area. He/she has to lobby other farmers to join the scheme in order to influence $\sum_s l_s$.

By rearranging equation (15), the new incentive constraint is

$$(15) \quad l_s = \alpha_s \Psi_s^{-1} P_w h_s - \Psi_s^{-1} \varphi_s + \frac{\beta \sum_s l_s \Psi_s^{-1}}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$$

Equation 15 is the updated response function of the agent and hence acts as the incentive constraint to the principal. As the response function directly depends on the ratio of the area under the contract scheme and total farming area, the contract scheme can persuade farmers to lobby each other in joining the contract at no cost to principal.

5.3.1.7 Updated participation constraint

We have already assumed that the reservation utility of farmer is κ_s i.e. the minimum gain that farmers bargain for,

$$(16) \quad r_s + \alpha_s P_w h_s l_s - \varphi_s l_s - 0.5 l_s' \Psi_s l_s + \frac{\beta l_s \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] = \kappa_s$$

Rearranging equation (16), the participation constraint is

$$(17) \quad r_s = \varphi_s l_s + 0.5 l_s' \Psi_s l_s - \alpha P_w h_s l_s - \frac{\beta l_s \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] + \kappa_s$$

5.3.1.8 Honorarium to the principal

$(1 - \beta) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right]$ is the final reward of the principal as stated in 5.3.6.

As we already explained, WUA is a benevolent principal who shares the profit among the members. But in order to ensure that the principal gets a minimum honorarium after distributing the bonus, an upper limit to β can be introduced. Similarly, a lower limit of β can ensure that farmers receive a minimum amount of bonus. These conditions can be specified as

$$\beta_L \leq \beta \leq \beta_U$$

Where ' β_L ' is the lower limit of β to fix the upper limit of reward for the principal while β_U specify the upper limit of β to ensure a lower limit of the reward of the principal. This lower and upper limit of β has to be set by a negotiation between the WUA and farmers but the actual (optimized) level will be one that maximizes the objective function, given the constraints including the constraint on β (Honorarium constraint). Whitford *et al.* (2005) argues that including the option of negotiation in principal-agent contracts results in a larger share of the surplus generated by the agent's actions is realised by the agent than in standard principal-agency theory. Hence the negotiation allows the subjects to attain Pareto optimal gains rather than trading off incentives for efficient risk sharing (Whitford *et al.*, 2005). This is realized here by allowing the agents to limit the principal's gain from their efforts by negotiation on upper and lower levels of β .

5.3.2 Summary of the P-A model

Let us hereby summarize the principal's objective function including incentive (IC) and participation (PC), bonus (BC) and honorarium (HC) constraints.

$$\text{Maximize PI} = \text{maximize } (1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s$$

Subjected to

$$l_s = \alpha_s \Psi_s^{-1} P_w h_s - \Psi_s^{-1} \varphi_s + \eta \frac{\beta \Psi_s^{-1} \sum_s l_s}{A^2} - (1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \quad (\text{IC})$$

$$r_s = \varphi_s l_s + 0.5 l_s' \Psi_s l_s - \alpha_s P_w h_s l_s - \eta \frac{\beta l_s \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] + \kappa l_s \quad (\text{PC})$$

$$B_s = \left(\frac{\beta l_s \sum_s l_s}{A^2} \right) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] \quad (\text{BC})$$

$$\beta_L \leq \beta \leq \beta_U \quad (\text{HC})$$

Here the parameter η is added to retain the mathematical equality of IC and PC when the market water price is higher than the price required for a full area allocation. As β is constrained with in the lower and upper limits, η makes sure that the principal is not demanding an allocation more than the full area under the WUA. The excess money gets distributed as bonus but does not affect the already optimized coefficients of l_s and r_s .

This revenue sharing contract links the individual effort to individual reward, which is a function of the water price. This condition is equivalent of having individual allocation of water rights to each farmer but the transaction cost of establishing, protecting and exchanging water rights can be a fraction of the latter.

5.4 Benefit of the market based water allocation in the Cauvery basin

Water trade in the Cauvery basin can lead to Pareto optimal increase in benefits compared to the status quo allocation in the river basin, only when the cost of purchasing the additional water rights is lower than cost of the using the alternative source of water by the WUAs of the demand side i.e. groundwater. In order to do it, it has to be proved that a price differential exist between the water right purchases and ground water extraction. The demand price of water can be estimated from the cost of ground water extraction while the numerical simulation of the P-A contract can be used to estimate the supply price of water rights. The following chapters are dealing these aspects.

6. GROUND WATER EXTRACTION AS AN ALTERNATIVE FOR SURFACE WATER RIGHTS AQUISITION: WEIGHING THE COSTS AND THE BENEFITS

It is evident that the demand for additional supplies of surface water for agriculture arises from WUAs holding less than sufficient surface water rights. Recall that all WUAs hold water rights according to their past water receipts in the conceptual frame described in Chapter 5. A typical strategy of farmers facing surface water shortage in the research area is to compensate the surface water deficit by the use of ground water. Costs of extracting water from this alternative source can be considered for estimating the price at which surface water purchase will be a viable option. If the farmer decides to use ground water as the alternative for additional surface water rights, he faces three sets of costs i.e. 1) investment costs 2) extraction costs and 3) externality costs. As extraction costs are heavily subsidised by both Tamil Nadu and Karnataka governments through highly subsidised electric power (see the section 2.1.2.3), this chapter look at the other two costs for determining the price of ground water. The price of groundwater is indirectly measured by considering the amortised investment costs and the external costs as a component of land prices at different locations with different ground water levels. The results are used in the next chapter to examine whether a price differential exists between the unit price of surface water rights and the estimated ground water price.

6.1 Investment costs in groundwater extraction

Ground water pumping requires substantial investment on constructing wells and installing pumping equipments in addition to energy cost of lifting the water out of the aquifer. In order to calculate cost of ground water extraction, we amortise the lumpsum investments to annuities (M).

$$(1) M = [V(1+i)^L i] / [(1+i)^L - 1]$$

Where 'V' is the compounded investment cost in Indian rupees at 2006 level. The rate at which we compounded the investment is 4 per cent and the same rate (i) is considered for amortisation as well. The average life of the bore well (L) is taken as 10 years. The present amortised cost of investment/ha include all the cost required to produce a successful well. It is to be noted that all bore wells drilled by farmer may not be successful in yielding water and a failed well may substantially increase the costs of ground water use. A sub-sample of 58 farmers, after removing outliers, is used in calculating the amortised values of investment (per ha) on bore wells. The amortised mean investment/ha is 5827 INR with high standard deviation of INR 4651 where the median investment is 4593 INR. The

amortised investment/ha for all farmers in the sample are presented in the figure 6.1

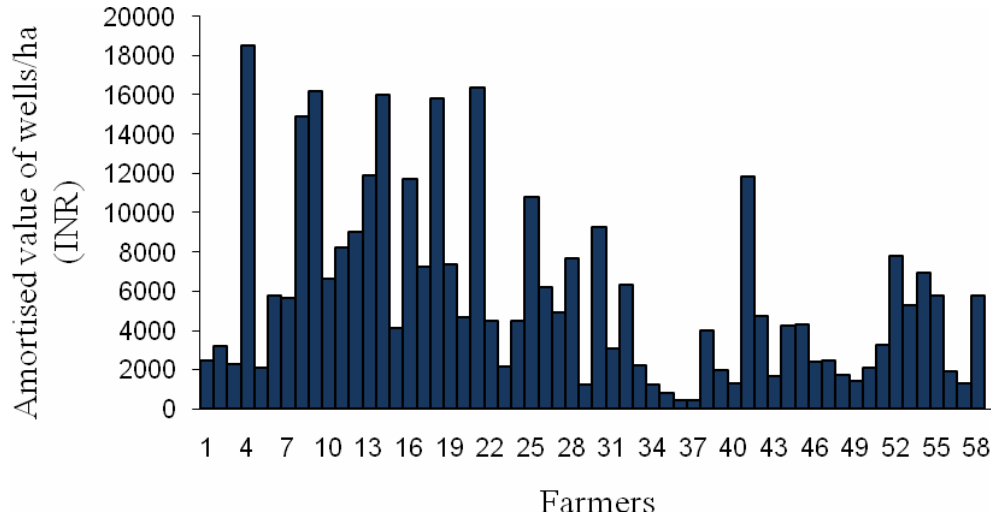


Figure 6.1 Amortised value / ha (INR) of borewells of the sampled farmers

6.2 Externality cost of pumping ground water

The simultaneous pumping of ground water by many farmers sharing the same aquifer can lead to over-drafting of groundwater. This in turn causes the sinking of ground water table over years which can be considered as an externality of inefficient surface water distribution in our case. In the following section, quantification of the externality using a hedonic regression on agricultural land prices is carried out. Such an approach is possible because the price of the bundled good, i.e. irrigated farm land, can be segregated with respect to different characteristics of the land parcel (Faux and Perry, 1999) which include the status of ground water availability for irrigation (represented by ground water level here). In addition, the short term benefit of ground water extraction for agricultural production exceeds the operational costs of extraction as electricity is subsidized in the research area (see chapter 2) and hence the effect of fall in ground water levels are not visible in output of profit figures. These reasons justify the use of hedonic pricing model to unravel the hidden costs of over extraction of ground water for irrigation.

6.2.1 Ground water levels in the Cauvery Basin

Before specifying the hedonic regression model, an overview of the ground water situation along the Cauvery River is presented in the figure 6.2. The average

water levels of surveyed agricultural land parcels in Cauvery Basin, aggregated over administrative districts of Karnataka and Tamil Nadu states (See chapter 2 for details of the primary survey) are depicted here.

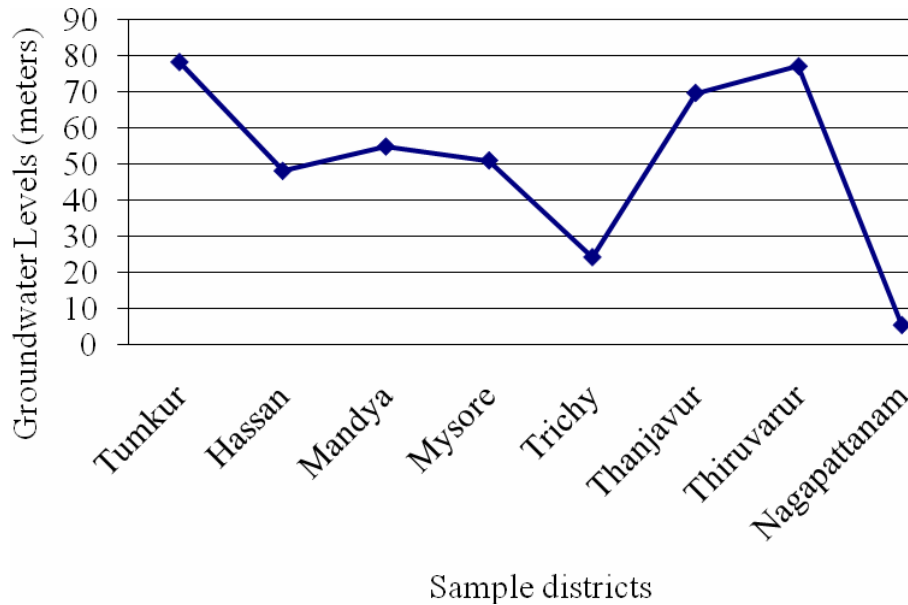


Figure 6.2: Average depth to the water tables from the surface in surveyed agricultural land parcels along Cauvery Basin

The average ground water table ranges from 24 meters to 54 meters below surface level in the river basin. The KRS (Krishnarajasagara Reservoir Project) and Mettur (Stanley Reservoir Project) dams, which are the main water reservoirs in the Cauvery River, are located roughly in the middle of the command area (See Chapter 2) and it can be noticed that groundwater level shows a decreasing trend (means depth to the water table from the ground surface is increasing) towards both ends from the centre except in the Nagapattanam district. Albeit ground water availability at 6 meters from the surface, it is unfit for irrigation purposes in this district due to sea water intrusion of the aquifer due to over extraction. It is to be notified that the agricultural land market in sampled villages of Nagapattanam district is reported to be dysfunctional due to this problem. Agricultural land transactions are seldom reported in this district.

6.2.2 Hedonic regression

Hedonic regression is widely used to estimate the value of attributes of land parcels especially residential properties (see Boyle and Kiel, 2001 for an extensive review) but applications in agriculture are not rare [For e.g. Palmquist and Danielson (1989), Xu *et al.* (1993), Faux and Perry (1999)].

6.2.2.1 Hedonic regression specification

The covariates of farm land prices are hypothesised to be 1) the soil quality, 2) the groundwater availability, 3) the road and the market access and 4) the bargaining power of the farmer. Soil quality is measured using an index based on farmer's own assessment of the farmland (from the survey). It should be noted that this is hidden information in the perspective of a prospective buyer. The groundwater availability is specified as the depth at which groundwater was available during the last cropping period. The depth of the ground water table also indicates the chances of having a successful cropping season if the surface water flow is inadequate. It is evident that groundwater availability is viewed as an insurance against crop failures in the research area due to irregular surface water availability (see the section 2.3.6). The road and the market access are measured using the distances to nearest road and market from each land parcel. As the size of the farm determines the ability of the farmer to successfully bargain, it is specified as a proxy of farmer's bargaining power.

As the observations are taken along the river stream, there is a physical connection among the sampled blocks and villages viz. the surface water flow. It is to be noted that water diversions in a village or block can influence the surface water availability and the ground water levels of neighbouring village or blocks. In addition, farm land price in one village or block influences the land prices in surrounding villages or blocks. So there is a social connection as well. But the both physical and social influence diminishes as distance from the village or block to the location of interest increases. Considering these peculiarities, the underlying spatial dependence in land prices is modelled as an isotropic spatial process i.e. the dependence between the land prices of two locations are specified as a function of Euclidean distance between them. This can be specified as the interaction of residuals in spatial regression. This type of specification of spatial processes is traditionally used in ecological and epidemiological studies (Raso *et al.*, 2006). Hence the land price becomes a function of neighbourhood characteristics along with its own features. There is an increasing interest in such spatial hedonic models but the applications in farming lands are limited in number [Eg: Geoghegan *et al.* (1997), Ready and Abdalla (2005)].

Let land price of i^{th} land parcel of j^{th} block be (L_{ij}) , its covariates be X_{ij} , the block specific random effect be θ_j and the natural log of L_{ij} follow a normal distribution.

$$(2) \quad \ln L_{ij} = \hat{\beta} \ln X_{ij} + \theta_j,$$

This double log version of hedonic regression is equivalent to a Box-Cox transformation ($\lambda = 0$) which is common in hedonic regression literature. Here $\hat{\beta}$ is a vector of regression coefficients. The spatial heterogeneity is modelled as location specific random effects, which specify a latent spatial process. The spatial random effect ($\hat{\theta} = (\theta_1, \dots, \theta_j, \dots, \theta_N)$) is assumed to follow a multivariate normal distribution with zero mean effect and the variance covariance matrix, ω i.e. $\theta_j \sim \text{MVN}(0, \omega)$. The ω can be expressed as a product of the standard deviations (σ) and the spatial correlation matrix, Σ i.e. $\omega = \sigma^2 \Sigma$. As already stated, this spatial correlation matrix is parameterised as a function of distance between the spatial locations. This means that the isotropic spatial process underlying spatial dependence among land prices is specified as a function of the distances between the spatial locations. The functional form is taken as an exponential one following conventions (Raso *et al.*, 2006), that is

$$\Sigma_{mn} = \exp(-\phi d_{mn})$$

where d_{mn} is the Euclidean distance between two blocks (m and n) while ϕ is the spatial correlation factor which controls the decay in correlation with increasing distance. The distances are calculated using the UTM coordinates of the block centre (x_m, y_m) and (x_n, y_n) . Some spatial modellers use a power exponential function to characterise the spatial correlation by assigning a power to the exponential form $[xp(-\phi d_{mn})^\kappa]$. The power κ is unity in the current specification (Raso *et al.*, 2006).

A summary of the variables used in the hedonic regression model and their description is given in the table 6.1.

Table 6.1: List of variables in the hedonic regression

Variables	Explanation	Unit
L_{ij}	Expected selling price per ha of i^{th} land parcel	Indian Rupees (INR)
Attributes of land parcel		
X_1	Distance to road from the i^{th} land parcel	Meters
X_2	water level in the i^{th} land parcel	Meters
X_3	Level of soil quality in farmer's opinion	Index
Determinant of Bargaining Power		
X_4	Size of i^{th} land parcel	Hectares
Spatial random effect		
d_{mn}	Euclidean distance between of m and n block centres	Distance between UTM coordinates of (x_m, y_m) and (x_n, y_n)

6.2.2.2 Hedonic regression estimation

Following a Bayesian model specification, prior distributions are adopted for the model parameters. Hereby the principle of conjugacy is used in selecting most of the prior distributions of the parameters. Vague normal distribution is chosen for all $\hat{\beta}$ parameters, inverse gamma prior is used for σ^2 . The ' φ ', the spatial correlation factor is allowed to vary between 0 to 0.94 at a distance of 10 kilometers and 0 to 0.085 at 400 Kilometers by the parameters by specifying the uniform distribution [uniform(-12, -5.3)]. All prior distributions used in the estimation are given in table 6.2.

Table 6.2 Prior Distribution of parameters

Parameters	Details	Priors
$\hat{\beta}$	Regression coefficients	normal (0, 0.00001)
φ	Spatial correlation parameter	$\ln \varphi \sim \text{uniform}(-12, -5.3)$
σ	Spatial variance	$\sigma^{-1} \sim \text{gamma}(0.001, 0.001)$

The software used for the spatial hedonic regression is 'Winbugs- version 1.4.1' and the code for the model is given in Appendix 1. Two sets of initial values are assigned to check the convergence of the parameter values. The initial values are generated by the software 'R' according to their assumed initial distributions. Markov Chain Monte Carlo simulation is employed in estimating the parameters. A burn-in of 5000 iterations is also set.

6.2.2.3 Hedonic regression results

All the estimated parameters of the hedonic regression except for the soil quality index and the road access variable are statistically significant. The value loss by the falling ground water levels in Cauvery Basin is quite apparent in the estimated parameter of that variable. The results assert the significant negative relation between ground water levels and land prices, which account for a loss of around INR 80,000 per hectare corresponding to a water level drop from 4 meters to 40 meters. The results also show significant neighbourhood effects in the land prices. Road access represented by the distance to road from each land parcel is found to have not exerting any significant effect on land prices, probably due to the fact that there is a low level of farm mechanisation and the land parcels are not usually sold for non-agricultural purposes. The soil quality index also appears to have little influence in the expected land values. This may be due to the fact that it is hidden information for the prospective land buyer. The farm size turns up to be a positive significant variable since it represents the bargaining power of a farmer with the prospective buyer. It can be seen from the results that all the spatially

assigned random effects are significant except the θ [7] representing the block Papanasam in Tamil Nadu. In summary, the agricultural land value in Cauvery basin is predominantly determined by the ground water availability, bargaining power of the farmer and neighbourhood conditions (captured in spatial random effects). The results are presented in the table 6.3 and the table 6.4.

Table 6.3: Hedonic regression results – coefficients of variables

Parameters	value	Standard deviation	t-statistic	MC error
α	12.08	0.5193	23.26	0.01674
$\beta_{distrad}$	0.05167	0.04338	1.191	3.33E-04
$\beta_{farmsize}$	0.104	0.04901	2.122	3.66E-04
$\beta_{levelwat}$	-0.1989	0.08016	-2.48	8.12E-04
$\beta_{soilqual}$ [2]	-0.01252	0.08857	-0.141	6.63E-04
$\beta_{soilqual}$ [3]	0.2789	0.1993	1.399	0.001595
$\beta_{soilqual}$ [4]	0.03864	0.281	0.1375	0.002097

Table 6.4: Hedonic regression results – spatial random effects

Θ	value	Standard deviation	t-statistic	MC error	Block	District
θ [1]	0.7046	0.3731	1.89	0.01701	Valangaiman	Thiruvarur
θ [2]	0.8285	0.3571	2.32	0.01704	Needamangalam	Thiruvarur
θ [3]	0.9674	0.366	2.64	0.01706	Mannargudi	Thiruvarur
θ [4]	0.9184	0.3551	2.59	0.01632	Mannachanallur	Trichy
θ [5]	1.052	0.3709	2.84	0.01696	Lalgudi	Trichy
θ [6]	0.8996	0.3658	2.46	0.01634	Ananthanallur	Trichy
θ [7]	0.278	0.3608	0.77	0.01632	Papanasam	Tanjore
θ [8]	1.154	0.3656	3.16	0.0171	Pattukkottai	Tanjore
θ [9]	1.172	0.377	3.11	0.01757	Orathanadu	Tanjore
θ [10]	0.9939	0.361	2.75	0.01672	Gubbi	Tumkur
θ [11]	1.308	0.3619	3.61	0.01708	Tiptur	Tumkur
θ [12]	1.263	0.3605	3.50	0.01712	Turuvekere	Tumkur
θ [13]	1.12	0.3508	3.19	0.01661	C.R. Patna	Hasan
θ [14]	1.262	0.3572	3.53	0.01674	Hole Narasipura	Hasan
θ [15]	1.68	0.3866	4.35	0.01802	Arkalgud	Hasan
θ [16]	1.025	0.3497	2.93	0.01659	Piriyapattana	Mysore
θ [17]	0.6586	0.3443	1.91	0.01599	Hunsur	Mysore
θ [18]	1.373	0.3644	3.77	0.01739	K.R. Nagar	Mysore
θ [19]	1.05	0.3539	2.97	0.01655	K.R.Pete	mandya
θ [20]	1.544	0.3561	4.34	0.01682	S.R. Patna	mandya
θ [21]	1.653	0.364	4.54	0.01727	Mandya	mandya

Effects of neighbourhood characteristics on land prices represented by θ_j can be better understood when these effects are translated into value terms. Values vary from INR 0.05 million to INR 0.7 million per hectare of agricultural land. In order to understand their magnitude, these figures can be compared with the mean land price in the sample (INR 0.4 million per ha) and maximum land price observed (INR 2.4 million per ha). Figure 6.3 shows the value of θ_j , arranged according to their distance from the tail end (from the same reference point) of the Cauvery River. This shows the spatial variability in land prices in Karnataka (Tiptur to S.R Patna) and Tamil Nadu (Ananthanallur to Pattukottai) in the geographical order.

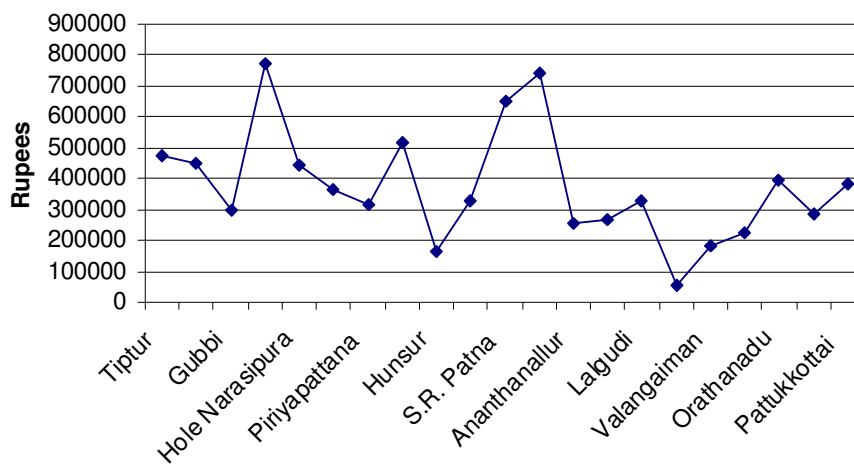


Figure 6.3: Estimated effects of spatial location on Land Prices in its geographical order

6.2.2.3 Fit of the hedonic regression

We used the coefficients of spatial hedonic regression and spatial random effects to predict the means of observed land values which show a good fit representing the predictive capability of the model (see the figure 6.4). In addition, we can verify the convergence by assigning two sets of initial values for all coefficients and all exhibited convergence.

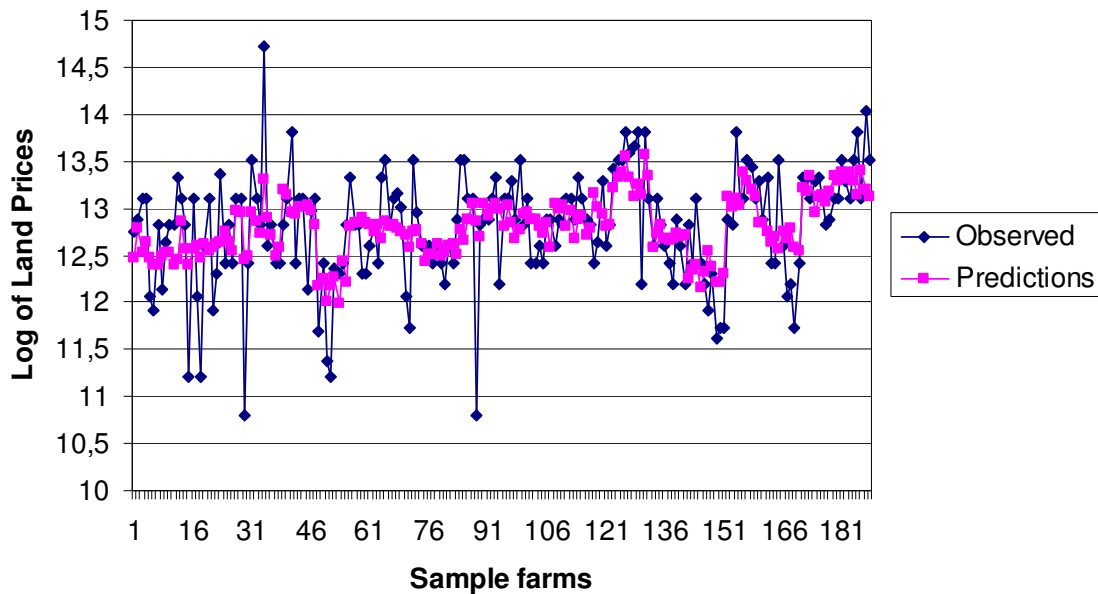


Figure 6.4: Observed and Predicted Land Prices for 189 sample farms

6.2.2.4 External cost of using ground water

To quantify the external effect, let us examine the relationship of the variables of our interest i.e. the ground water levels and the land prices which then is the basis for the water price evaluation. This relationship is portrayed in figure 6.5. It can be seen that the agricultural land prices are falling along with the ground water levels, notably, at a diminishing rate. The value loss decelerates substantially when water level crosses 40 m (≈ 130 feet) below ground level or in other words, the major portion of value loss happens before it falls to 40 meter below the surface level. A fall around a foot per year (1 foot = 0.3048 meter) can cause a land value deterioration of INR 947 (from a depth of 9 meters) to INR 151 / ha (from a depth of 43 meters) per year. A fall of one foot per year aggregates to a 3 meter fall per decade. The sampled basin districts are classified by the central ground water board as areas of water level sinking over 2 meters per decade. Hence land value loss per foot decrease in water table can be taken as the external cost. It is been found that the land value reaches around the value (per ha) of rainfed land when the water table sinks 40 meters below the ground level.

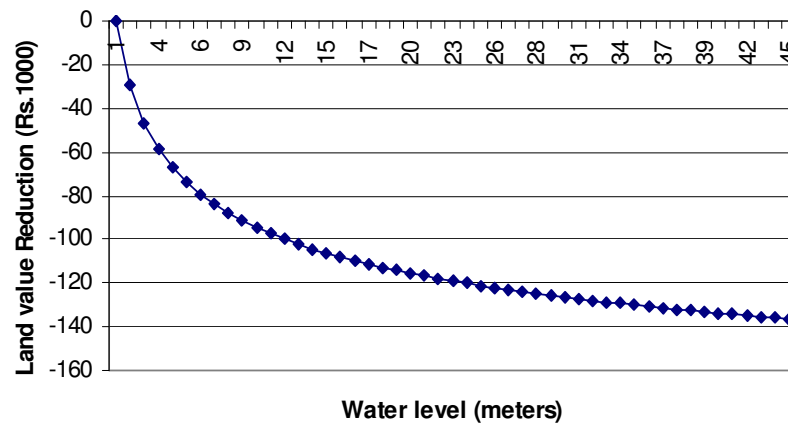


Figure 6.5: Falling ground water levels and land value reduction in Cauvery basin

6.3 Demand price of surface water right

As the amortised mean investment per hectare is 5827 INR and the external cost ranges between INR 947 (from a depth of 9 meters) to INR 151 per hectare, it can be seen that the average cost of using ground water per hectare by the WUAs at the demand side is approximately 6000 INR to 7000 INR per hectare per year. For an average farmer who meets 50 percent water shortage by ground water pumping for two season paddy crop (10000 cubic meters/ ha), this account to 0.6 INR to 0.7 INR per cubic meter. This figure can be taken as the demand price of surface water rights as the surface water right price exceeding this level makes the ground water extraction to be the cheaper alternative. It is to be noted that the operating costs of pumps are not considered in this calculation as electricity is heavily subsidised in these regions for political gains. If we add the real operating costs also to the costs of using ground water, there will be a considerable increase in the demand price of surface water. The next chapter examines whether the existing demand price can generate sufficient water rights reallocation.

7. ESTIMATING THE SUPPLY PRICE OF WATER RIGHTS: A NUMERICAL SIMULATION OF THE PRINCIPAL-AGENT MODEL

7.1 The principal-agent specification

The principal-agent scheme outlined in the chapter 5 is the following: The principal (WUA) has an objective function,

$$\text{Maximize PI} = \text{maximize } (1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s$$

Subjected to incentive, participation, bonus and honorarium constraints,

$$l_s = \alpha_s \Psi_s^{-1} P_w h_s - \Psi_s^{-1} \varphi_s + \eta \frac{\beta \Psi_s^{-1} \sum_s l_s}{A^2} (1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \quad (\text{IC})$$

$$r_s = \varphi_s l_s + 0.5 l_s \Psi_s l_s - \alpha_s P_w h_s l_s - \eta \frac{\beta l_s \sum_s l_s}{A^2} \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] + \kappa l_s \quad (\text{PC})$$

$$B_s = \left(\frac{\beta l_s \sum_s l_s}{A^2} \right) \left[(1 - \alpha_s) P_w h_s \sum_s l_s - (1 - \alpha_s) \sum_s r_s \right] \quad (\text{BC})$$

$$\beta_L \leq \beta \leq \beta_U \quad (\text{HC})$$

As the principal would like to maximize its gains, he offers the specified incentive scheme and shares the profit as a team incentive for joining the contract. The principal's instruments, to invoke the optimal response from farmer members, are: 1) an amount paid in advance for joining the contract to farmer 's', i.e. r_s ; 2) the revenue share offered to farmer 's', i.e. α_s ; and 3) the profit share to farmer 's', B_s . Farmer 's' respond to the incentives by allocating a part or the whole of his/her farming area, l_s to water saving mode of cultivation and lobbying other farmers to join the contract.

7.2. Data for the empirical simulation

For an empirical simulation, a hypothetical water user association is generated using land holding data which has been collected during the primary survey so that it can be a representative one. In this Water User Association (WUA), there is a total farm area of 565.08 ha (See Chapter 2 for details) held by 241 member farmers. For simplicity, we assume that all farmers of this hypothetical water user association cultivate paddy which is the predominant crop of the Cauvery Basin. For the purpose of estimating the parameters and specifying the variables for the

numerical simulation of the envisaged principal-agent specification, secondary data is used along with primary data. Let us examine the parameters and variables in the above stated P-A model one by one.

7.2.1 Calibration of exogenous parameters

A. Rate of water saving per hectare (h_s): This rate is associated with the water saving technique that can be employed in the farmer’s field. A set of techniques that can be used for water saving in the research area is given in table 7.1 (Palanisami *et al.*, 2003). The main feature of the listed techniques is that they cost labor but require less or no capital investment. These techniques are suitable for small farmers in developing countries (India) who are generally short of capital. It is to be admitted that this list is not exhaustive but the intention is to demonstrate a few of them. After inspecting the efficiency of available techniques (10-48 %) and farmer’s average efficiency levels, it is decided on a figure of 20 per cent as the value of h_s . In quantitative terms, this is equivalent to 2000 cubic meter of water ($h_s = 2000 \text{ m}^3$) as average water consumption for raising paddy is 10000 cubic meters per hectare per crop. This is considered reasonable in comparison with other studies (Belder *et al.*, 2004, Kongchum, 2005, Yang *et.al*, 2007)

Table 7.1: Water saving practices and their potential in rice farming

Water saving Practices	Water saving potential
Replacing continuous irrigation systems with irrigation to a depth of 5 cm when soil reached saturation level	30-48 % water saving
Constructing earthen hand bunds inside existing field bunds	20-25 % water saving
Direct seeding	10 % water saving
System of rice intensification (including intermittent wetting and drying)	30 -40 % water saving

Source : Compiled from Palanisami *et al.* (2003)

B. Price of water (P_w): Another parameter of interest is price of water (P_w) which is equivalent to the unit price of water right sold in the water market. As each water user association is assumed to be a price taker, the price is an exogenous variable determined by demand and supply factors. We accomplish sensitivity analysis of the price parameter by analyzing the size of the gains for farmers and the principal at a range of water right prices.

C. Reservation utility (κ)

Farmer's reservation utility per unit area is taken to be a moderate additional gain of 250 to 500 Indian rupees per ha. This is equivalent to producing an additional 0.75 to a 1.5 quintal of rice per ha respectively. The figures are calculated based on the support price offered by the Govt. in the region (Rs. 5 / Kilogram) and the cost benefit ratio of rice in the research area (1.5), notably, during the time period of the research work.

D. Cost function parameters (ϕ and Ψ)

As it is previously stated, all water saving techniques demands additional labour. Since many of the farmers can manage the additional labor requirement of the water saving mode of production by family labour, ideally, a willingness to accept exercise could be used to determine an average payment at which they may start switching over to water saving mode of cultivation. But, due to the fact that willingness to accept exercises quite often result in exaggerated figures (Horowitz and McConnell 2002), the willingness to pay (WTP), a penalty for avoiding a switching over to water saving mode of cultivation, is estimated. In the WTP exercise, farmers were presented with two choices, either they could pay an additional charge per hectare or adopt a water saving mode of cultivation. The details of the WTP exercise are given in the next section. We used the average willingness to pay (WTP) to avoid the switch over (equivalent to average payment at which the switch over to water saving mode of cultivation) as the parameter ϕ , i.e. the intercept of the cost function. Regarding the slope parameter of the cost function (Ψ), a moderate slope is assumed.

7.2.2 Contingent Valuation Exercise

As already stated, the hypothetical scenario presented to the farmer is a dichotomous choice between paying an additional water charge (penalty) and adoption of water saving mode of production. A waiver of the existing water charge is also offered to the farmer, if he/she adopts the water saving mode of cultivation. A double bounded form of contingent valuation is employed. (Hanemann, Loomis and Kanninen, 1991) In this format, the farmer is presented with a random penalty bid, and depending on farmer's response to the initial bid, a higher or lower subsequent penalty bid is presented. The follow up penalty bid is halved if the farmer is willing to switch over to water saving mode of cultivation instead of paying the initial penalty. The follow up penalty is doubled if the farmer is ready to pay the initial penalty. There are four possibilities of responses viz. pay-pay (PP), pay-adopt (PA), adopt-pay (AP) and adopt-adopt (AA). Here the pay-pay response means that the farmer is ready to pay the penalty at both level of bids (initial and higher follow up bid) as well as he will

not adopt any water saving measures in his field. Pay-adopt response means that farmer decides to pay at the initial bid level, but ready to shift to a water saving mode of cultivation when faced with a doubling of the additional water charge. These four outcomes of the bidding procedure viz. AA, AP, PA, PP place the true willingness to pay the penalty (WTP) in intervals of $(-\infty, V_i^L)$, (V_i^L, V_i) , (V_i, V^H) , $(V^H, +\infty)$ respectively and are coded as 1, 2, 3 and 4. V_i represents the value of the initial bid presented to i^{th} farmer while V_i^H represents a bid higher than the initial bid while V_i^L represents the bid lower than the initial bid. The bid structure is designed a-priori and the initial bid ranged from INR 100 to INR 600 per hectare, the higher bids varied from INR 200 to INR 1200 and the lower bids varied from INR 50 to INR 300 per hectare. The empirical bid structure and the response categories are given in the Table 7.2. It can be seen that there is a tendency to adopt water saving modes if cultivation conditions increase as the bid increased. In the experiment, only 9 farmers out of 240 were willing to pay the penalty at both penalty bids presented to them. The number of farmers, who were willing to adopt the water saving modes in their production at both bids, is 168 (70 %).

Table 7.2: Responses to different penalty bids categories

Bid category (First bid- Higher bid -Lower bid) in Indian Rupees (INR)	Responses			
	Adopt-Adopt	Adopt-Pay	Pay-Adopt	Pay-Pay
600-1200-300	32	5	1	1
500-1000-250	25	2	6	3
400-800-200	39	2	2	0
300-600-150	31	11	0	0
200-400-100	30	6	1	1
100-200-50	11	19	8	4
Total	168	45	18	9
Grand total	240			

7.1.2.1 Econometrics of doubled bound contingent valuation

Following Hanemann, Loomis and Kanninen (1991) the probability (Π) of getting a ‘pay’ response to the first bid followed by a ‘pay’ response to second bid (PP) is

$$(1) \Pi_i^{PP} = 1/(1 + e^{-(\alpha + \beta V_i^H)})$$

Where Π_i^{PP} follows a logistic function. Similarly, probability for AA, PA and AP responses by i^{th} respondent are

$$(2) \Pi_i^{AA} = 1 - 1/(1 + e^{-(\alpha + \beta V_i^L)})$$

$$(3) \Pi_i^{PA} = 1/(1 + e^{-(\alpha + \beta V_i^H)}) - 1/(1 + e^{-(\alpha + \beta V_i^L)})$$

$$(4) \Pi_i^{AP} = 1/(1 + e^{-(\alpha + \beta V_i)}) - 1/1 + e^{-(\alpha + \beta V_i^L)}$$

Mathematically, the log-likelihood function of double bounded model is

$$(5) LDB = \sum_{i=1}^n r_i^{PP} \ln \Pi^{PP}(V_i^H) + r_i^{AA} \ln \Pi^{AA}(V_i^L) + r_i^{PA} \ln \Pi^{PA}(V_i, V_i^H) + r_i^{AP} \ln \Pi^{AP}(V_i, V_i^L)$$

Where LDB is the natural log of the double bounded log likelihood and r_i^{PP} , r_i^{AA} , r_i^{PA} and r_i^{AP} are binary variables corresponding to the response category of i^{th} respondent.

7.2.2.2 Calculation of the mean willing to pay

The coefficients, α and β of the double bounded dichotomous choice CVM and the mean willingness to pay and its confidence intervals are estimated using the referendum CVM programme written by Cooper, J.C (1999). Following Hanemann, Loomis and Kanninen (1991), the mean willingness to pay is calculated using the equation, $E(WTP) = -1/\beta$

7.2.2.3 Double bounded logit estimation results

As a first result, the bid variable is significant (see Table 7.3) and its sign is negative as expected. The mean willingness to pay estimated from the double bounded logit equation is INR 105.5 per hectare with a 95 per cent confidence interval of 86.3 to 129.5. The Krinsky and Robb procedure (Park et al., 1991) is used for calculating the confidence intervals. It is to be noted that the CVM question included a waiver in existing water charge, INR 100/hectare. It means that the willingness to pay of the farmers to avoid a transition to a water saving technique is INR 205.5. In this scenario a farmer with an average area of 3 hectares has to pay around INR 617 per farm, if the water saving measure is not adopted. This is equivalent to the wage of 10-15 labour days according to prevailing wage rates. It may justify the construction of earthen hand bunds inside existing fields or adopting intermittent irrigation. Also it is possible that a farmer is estimating the opportunity costs of labour less than the prevailing wages as he offers his own labour for the water management activities.

Table 7.3: Double bounded logit regression results

Variable	Coefficients	Standard error	t-Statistic
Constant	0.19241	0.2165	0.8889
Bid	-0.007527	0.0009464	-7.953

7.2.3 Endogenous variables

The endogenous variables are principal’s instruments and the farmer response. The principal’s set of instruments for invoking an optimal response from farmer members are: 1) r_s , the initial payment to convince the risk averse farmers; 2) α_s , the revenue share offered to farmer ‘s’; and 3) B_s , the bonus or the profit share to farmer ‘s’. Farmer ‘s’ respond to the incentives offered by the principal by allocating part or the whole of his/her farming area, l_s to water saving mode of cultivation. The farmland area of each farmer is taken as their maximum possible contribution to the pool of area under water saving mode of irrigation in each WUA.

Descriptions of endogenous and exogenous parameters and variables in the P-A model are given in table 7. 4. The program code for the simulation of agent’s behaviour according to principal’s instruments is written in GAMS software. The GAMS code for the P-A model is given in the appendix 2.

Table 7.4: Description of parameters and variables of the contract scheme

	Description	Value	Unit	Remarks
Parameters				
h_s	Conversion coefficient for converting land area under water saving technology employed by farmer ‘s’ to its water saving equivalents	2000	Cubic meter	Only technologies which can save at least 20 percent of water is considered
P_w	Price of water	0.2-0.4	Indian Rupees/ cubic meter	Determined by demand and supply conditions
κ	Reservation utility of the farmer per ha	250-500	Indian Rupees	
φ_s	The intercept of cost function	205	Indian Rupees	Estimated from a contingent valuation exercise
Ψ_s	Slope of cost function	20	Indian Rupees	Means a cost escalation of 500 INR for a farmer holding 5 hectares
Variables and restrictions				
r_s	Amount paid in advance for joining the contract	Endogenous	Indian Rupees	

α_s	the revenue share offered to farmer 's'	Endogenous		
β	the profit share offered to the all WUA members	Endogenous		
β_L	The minimum profit share offered to members	0.8	Indian Rupees	Limits the maximum profit share (20%) of the principal
β_U	The maximum profit share offered to members	0.9	Indian Rupees	protects the minimum profit share (10%) of the principal
B_s	Bonus to individual farmer	Endogenous	B_s	Bonus to individual farmer
l_s	Land area under the contract scheme for the farmer 's'	Endogenous	Ha	l_s is less than or equal to total farm area of the farmer 's'

7.3 Results of the numerical simulation

Numerical simulations of the contract scheme presented in 7.1 are carried out to estimate the optimised values of principal's instruments (r_s , α_s and B_s) and the farmer's response, l_s . Various scenarios of water right prices and reservation prices are simulated.

7.3.1 Optimised values of endogenous variables

For the initial run of the principal-agent model, we have taken the reservation utility (κ) to be 250 Indian rupees (INR) and simulations at the water prices (P_w) of 0.2, 0.3 and 0.4 Indian rupees per cubic meter are conducted. All other parameters are kept as specified in table 7.4 (a ceteris paribus assumption). In this simulation, a water price of INR 0.2 ($P_w = 0.2$) results in an aggregate area allocation ($\sum_s l_s$) of 496.2 hectares (88% of the total area) to a water saving mode of cultivation. This corresponds to water saving of 0.9 million cubic meters. The principal gives the INR 229.5/ha as average initial payment (r_s). The average revenue share (α_s) is 0.48, corresponding to an average payment of INR 111/ha for the farmers joined in the scheme. In addition, the cooperative principal shares a bonus of INR 26692 ($\beta = 0.9$) among the farmers. Nevertheless, the principal's net income is limited to INR 3845. Figure 7.1 displays the optimised values of α_s in each farm at the water price of INR 0.2.

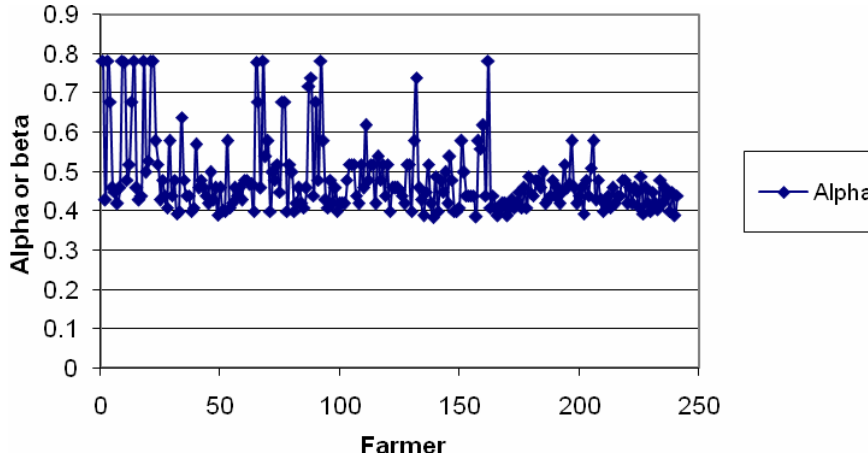


Figure 7.1: Values of the principal’s instruments α_s and β_s at the water price of INR 0.2

The principal offers increasing bonus (B_s) and initial payment per farm (r_s) as the farm size increases. But the initial payment (r_s /ha) for each additional hectare offered by the farmer shows a diminishing trend. It means that the principal should offer a higher initial payment per hectare for small farmers who are risk averse. These relations at a water price of INR 0.2 ($P_w = 0.2$) is displayed in figure 7.2. In case of bonus per farm, the principal offers it according to the total farm area allocated to the water saving practices in the whole WUA so that it invokes a team incentive to lobby other farmers.

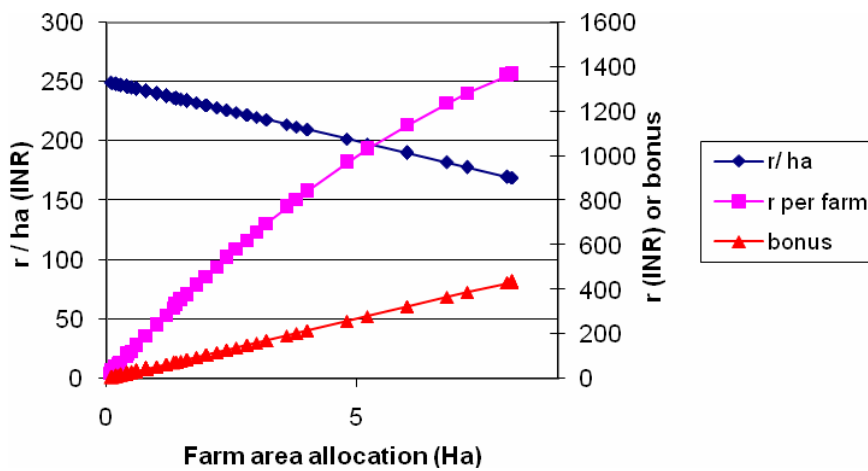


Figure 7.2: Relation of r_s per ha, r_s per farm and bonus (B_s) per farm to the farm size at water price of 0.2 INR

When the water price is increased to 0.3, the aggregate area under the revenue sharing for water saving contract ($\sum_s l_s$) increased to 556.05 ha. It is the whole

area under the WUA. The net principal income increased here to INR 35544. The principal distributes INR 137947 (INR 247/ ha) among the members as bonus. At a higher price of INR 0.4, the cooperative principal distributes INR 229257 as bonus ($\beta=0.8$).

The numerical simulation proves that the WUA, as principal, is able to ensure participation of farmers in the water saving contract scheme by offering an initial payment (r_s), revenue share (α_s) and the bonus share (B_s) and thus it achieves a maximum allocation of land to the suggested water saving mode of cultivation or irrigation by farmers. It also proves that a water price of INR 0.3 induce all farmers to switch over to water saving cultivation in response to the principal's instrument. The principal also can realise a decent remuneration for its effort.

7.3.2 Impact of the bonus specification

To prove the relative advantage of the bonus scheme, each set of results in the previous simulations are compared with results of the contract scheme with out the bonus specification. When the bonus scheme is dropped, the cooperative nature of the principal is lost and it becomes a normal profit making principal. Let us term the contract scheme presented in the section 7.1 as the cooperative contract and the other with out bonus as profit oriented contract.

At the water price of INR 0.2, ($P_w = 0.2$), the aggregate area allocated to water saving practices under the cooperative contract is 496.2 hectares (88% of total area) while it is only 456.6 hectares (81% of total area) when the principal is a profit oriented one. An additional 40 hectares show the significance of the bonus scheme. Nevertheless, the principal's net income is limited to INR 3845 while INR 26985 is the income of profit making principal. The cooperative principal gives the INR 229.5/ha as initial payment (r_s) and an average revenue share (α_s) of 0.48, corresponding to an average payment of INR 111/ha for the farmers joined in the scheme while profit oriented principal gives INR 219/ha as initial payment and a revenue share of 0.6 corresponding to an average payment of INR 121/ ha. In addition, the cooperative principal shares a bonus of INR 26692 ($\beta=0.9$) among the farmers but profit orient principal does not offer any bonus.

At a water price of INR 0.3, the aggregated area under the cooperative contract is 556.58 ha while the profit oriented one manages 522.84 ha, where there is a difference around 35 hectares. The net principal income increased here to INR 35544 in the former case while the latter achieved INR 102235. The initial payments are comparable in both cases but profit oriented principal offers higher revenue shares, an additional INR145/ha. In converse, the cooperative principal distributes INR 137947 (INR 247/ ha) among the members as bonus. In this case

we have to be remind the reader that the total revenue of the cooperative principal is high as the total area under the contract. At a higher price of 0.4, the difference between the both contracts in achievement of aggregate area gets reduced to 10 hectares. Nevertheless, the members achieve a higher income under the cooperative contract as the principal distributes INR 229257 as bonus ($\beta=0.8$). The main feature is that the contract with bonus specification achieves the maximum area allocation at a price around INR 0.3 per cubic meter, while the contract with out the bonus specification achieves it only around INR 0.45 per cubic meter. In addition, it can be seen that the cooperative principal is better performing especially at lower water prices which is an important feature as the higher prices of water may not be realistic in real life situations.

To highlight the effect of the bonus, notably as a team incentive (use of correction factor on bonus distribution), we are looking at the relation between bonus per hectare and aggregate area under the contract scheme at a water price of INR 0.4. The relationship is depicted in figure 5. It is clear from the figure that lobbying other farmers to join the contract can lead to substantial individual gains.

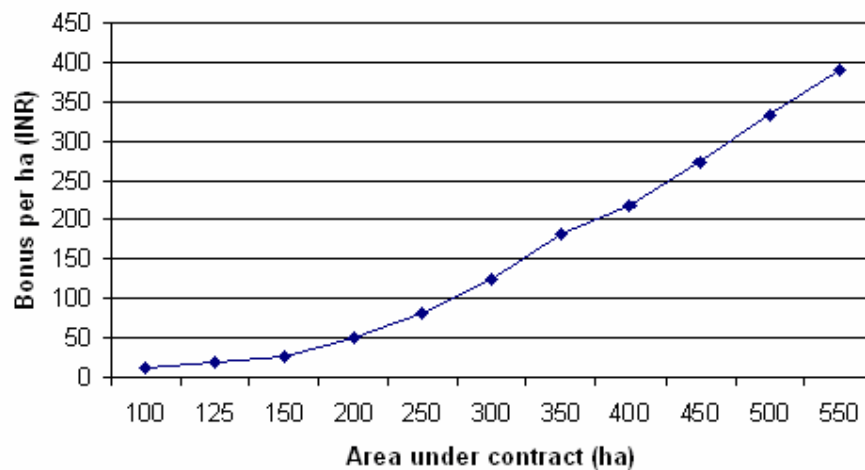


Figure 7.3: team incentive: relationship between bonus per ha on aggregate area under the contract

7.4 Evidence from research area

It is proved here that water saving and reallocation will respond to water market prices if farmers are coordinated by the revenue sharing mechanism. In the research area, an exercise to coordinate the water use in Siddhamalli taluk in Tanjore district in Cauvery Basin has already been carried out by the district authorities through synchronising farming activities and regulating water flows in a 2000 hectare farm block cultivating paddy crop. The practice of draining of water from one paddy field to another was also controlled simultaneously. As a

result, the water requirement of the block got reduced to half of the normal allocation in this experiment (50 percent saving in water). A similar experiment was carried out in Krishna River Basin as well and realised similar results (CWDT-VOL V, 2007). These experiences indicate that the coordination mechanism generating sufficient incentives like the one proposed here can institutionalise the aggregate water saving achieved in such experiments in presence of an interstate water market.

7.5 Comparing water rights purchase and ground water use

It has been already stated that (see chapter 6) the average cost of using groundwater by the demand side is around 6000 INR to 7000 INR per hectare per year when the cost of externalities is also considered. Hence it is evident from the figures that a surface water right price less than INR 0.6 / cubic meter is economically viable for a farmer who meets 50 percent of irrigation requirement by ground water pumping for two season paddy crops (10000 cubic meters). Purchasing water rights is equivalent to 10000 cubic meters at the price of 0.3 INR amounts to 3000 INR, which is substantially lower than the cost of ground water usage. It is to be noted that we did not consider the operating cost of pumps as electricity is heavily subsidised in these regions for political gains. If we add the real operating costs also to the cost of using ground water, considerable gains of water trading becomes visible. This proves the potential of surface water reallocation by the water rights market to Pareto optimally increase the benefits for all stakeholders in Cauvery Basin.

8. CONCLUSIONS OF THE STUDY AND THE POLICY RELEVANCE OF THE PROPOSED WATER RIGHTS MARKET IN THE CAUVERY BASIN

8.1 Summary of the main findings

The current study examines the historical, political, economic and legal aspects of the Cauvery River water conflict and develops an economic solution for the water sharing issue. In the historical perspective, the study describes the evolution of the current scenario of existing demands exceeding the available water supply in the River. The historical review of development of irrigation systems in the river basin starts from the construction of Cauvery Anicut by an early Chola King, Karikala Cholan in 200 A.D to regulate the flood waters in Cauvery River. It also mentions various dynasties ruled the Cauvery basin area and their contribution towards development of irrigation systems in the River basin. The conflict situation in River water sharing arose in the 19th century between the Wodayar Kings in the Mysore state (upstream) and the British colonial rulers of the Madras state (downstream). The treaty that both parties forged in 1892 had conditions restricting water diversions by Mysore state and the allowing copious river water flows to Madras state which facilitated the evolution of an irrigation system based on the rice farming with flood irrigation in the downstream part of the basin. The 1892 agreement expired after 50 years and the upstream state, Karnataka (previously Mysore) developed its irrigation systems to compensate the underinvestment in its irrigation systems during the period of the treaty. This pattern of development left the upstream and downstream irrigated areas to compete for the same resource and eventually exacerbated the conflict on water sharing. The body formed to negotiate a treaty on initial water allocation, Cauvery Water Dispute Tribunal could not give a final verdict that is acceptable for all states involved in the water sharing conflict. In this scenario, the current study 1) looks at the reasons for the lack of political interest in cooperating in the formation of a water allocation treaty, 2) reviews various legal, economic and geographical instruments in water sharing and finally 3) develops a water market solution for the water sharing issue so that the focus will be on the economic value that can be realised from water rather than its quantity allocation. In addition, the study looks at 4) the externalities of using ground water as an alternate source of water instead of an efficient surface water allocation system.

8.1.1 Insights from the field research

The systematic examination of the data on Cauvery River basin from secondary sources gives valuable inputs to the development of water market solution

suggested in the study. The pattern revealed from the data on surface and groundwater availability and its use suggest the inefficient use of surface water and over extraction of ground water sources in the river basin. It is also evident that agriculture is the principal consumer of the river water and domestic and industrial demands are comparatively miniscule. In the agricultural sector, rice farming is the activity that accounts for a major share of the water use in agricultural sector and currently employs the inefficient continuous flooding method of irrigation. This throws light on the necessity of building institutions facilitating irrigation efficiency gains at farm level and water allocation efficiency at the basin level.

In the farm level data from the primary survey of 240 farmers belonging to 24 villages from 24 blocks of 8 Cauvery River basin districts in Karnataka and Tamil Nadu, reveals how the inefficiency at the system (basin) level affects the farmers and how the inefficiency of irrigation practiced by farmers affects the system efficiency. The irrigation water demand at current technology exceeds the water availability in the river basin and hence to compensate the deficit, farmers use ground water as an alternate source. In the absence of a formal treaty in surface water sharing, there prevails an uncertainty in timing of water transfers among states each year, which gets translated to inefficiencies in water distribution to farmers. This also drives farmers in adopting bore wells for groundwater extraction. In a nutshell, both quantity and quality of irrigation water supply steer farmers to adoption of groundwater as the preferred source of water. Note that the term 'quality' of water supply does not address the physical qualities of water rather focus of the quality of the distribution system. From the farm level data, it is evident that current ground water extraction rates exceed the recharge and ground water levels are falling at an alarming rate.

The primary survey reveals the picture of an agricultural system dominated by small farmers (<2 hectares), with median age exceeding the median age of the county by 20 years, having an average education level of 8 years of schooling, cultivating predominantly paddy, sugarcane or millets, facing uncertainty of surface water supplies over quantity and timing, extracting groundwater more than its recharge and employing inefficient irrigation practices and supporting a family of six members. The farmers avail credit from formal and informal sources for investing in ground water extraction even at interest rates far exceeding the formal bank rates.

The survey also revealed that the farmers will not vote to any political party that is willing to compromise on surface water quantity allocation to the respective

states and a majority of farmers are ready to vote for a party which promises full subsidisation of electricity for pumping ground water.

8.1.2 Political prisoner's dilemma in water sharing

Water availability is the factor that decides the social strata of the farmer or in other words, the access to water decides whether he belongs to a category of poor farmers who are dependent on stochastic rainfall for crop cultivation or the group of prosperous farmers having access to surface or ground water sources (or both). Hence his/her the political choices depend on the policies of a political party regarding surface and ground irrigation water availability. Political parties translate this sentiment to votes by wooing them by policy promises such as subsidies for electricity for groundwater pumping. In this scenario it is optimal for any party to take a position of noncooperation in water sharing agreement that compromises the current or historical water allocation levels in the Cauvery river basin. This strategy makes sure that the competing party will not take undue advantage in election by proclaiming their non-cooperative stand point. The insight from this result is that there is a need to decouple initial water allocation and the money that the water represents.

8.1.3 Water market as a solution for water sharing issue

In order to decouple water rights (or initial water allocation) from the net benefits that the water represents, a water right market can be introduced. In the presence of a water rights market, the final allocation of water in the river is decided by demand and supply conditions even if the initial allocation is decided through a water sharing agreement. Even though this solution is already suggested by many researchers, the major bottlenecks in implementation are the high transaction costs of (1) establishing the prerequisites of a functional water market i.e. assignment of the initial water rights and the provision to physically regulate the water flow to individual fields, (2) the high transaction costs of finding a suitable and willing buyer for the individual water rights and (3) the associated administrative costs of reassigning the water entitlements. In order to reduce the establishment and transaction costs of a water rights market, downsizing of number of players in the market by allocating rights to farmer communities (water user associations) instead of individual farmers is proposed. In this market water rights can be bought and sold by water user associations.

The immediate question to be answered is how the coordination of the water user association can be achieved so that the community behaves as a single entity in the market. In the presence of the water rights market, each WUA has the possibility of employing water saving techniques in its command area and selling

the surplus rights if the water rights prices justify the cost of employing water saving techniques. The challenge is how to coordinate the use of water saving techniques in individual farms so that aggregate water surplus can be traded. The assumption here is that the WUA (seller) holds sufficient water rights for irrigation under current technology. The revenue sharing for water saving contract between water user association and the farmer offers a solution for this problem. The revenue sharing for water saving contract designed using a principal-agent model offers three instruments to coordinate action of farmers 1) The fixed amount paid to farmer in advance for joining the contract 2) a variable revenue share 3) the profit share from the water trade. The profit share is based on the aggregate water surplus generated so that it can act as a team incentive. It is to be reminded that water trade in the Cauvery basin can lead to Pareto optimal increase in benefits compared to the status quo allocation in the river basin, only when the cost of purchasing the additional water rights is lower than cost of the using the alternative source of water by the WUAs of the demand side i.e. groundwater. So to estimate the price below which water rights become a viable alternative, cost of ground water extraction has to be calculated.

8.1.4 Estimation of groundwater extraction costs

The three components in ground water extraction costs are 1) investment costs on bore well and pumping equipments 2) pumping costs i.e. electricity charges 3) the externality costs of falling ground water levels. The amortised mean investment cost per hectare for establishing bore wells calculated from the sample is 5827 Indian Rupees. As electricity is heavily subsidized, the pumping costs are not considered in the costs at the farmer side. The externality cost is estimated through a spatial hedonic regression of water table levels on land prices. A Bayesian framework is used in the spatial estimation procedure so that neighbourhood effects on land prices can be explicitly modelled. The results of the hedonic regression revealed a loss of around INR 80,000 per hectare corresponding to a water level drop from 4 meters to 40 meters. It is been found that the land value reaches around the value (per ha) of rainfed land when the water table sinks 40 meters below the ground level. A fall around a foot per year (1 foot = 0.3048 meter) can cause a land value deterioration of INR 947 (from a depth of 9 meters) to INR 151 / ha (from a depth of 43 meters) per year. A fall of one foot per year aggregates to a 3 meter fall per decade. The sampled basin districts are classified by the central ground water board as areas of water level sinking over 2 meters per decade. Hence land value loss due to a fall in ground water level by 0.3048 meter is taken as the external cost. Hence it can be seen that the average cost of using ground water per hectare by the WUAs at the demand side is approximately 6000 INR to 7000 INR per hectare per year. For an average

farmer who meets 50 percent water shortage by ground water pumping for two season paddy crop (10000 cubic meters/ ha), this account to 0.6 INR to 0.7 INR per cubic meter. This figure can be taken as the demand price of surface water rights as the surface water right price exceeding this level makes the ground water extraction to be the cheaper alternative.

8.1.5 Supply price of water rights

In order to see whether a sufficient price differential exists between supply and demand prices of water rights, an empirical simulation of the principal-agent model of the revenue sharing for water saving contract is carried out. The parameters of the model are estimated from both primary and secondary sources. Cost function parameters of the water saving technique are estimated by a contingent valuation exercise. Here a willingness to pay exercise is used to determine an average payment at which they may start switching over to water saving mode of cultivation. The doubled bounded dichotomous contingent valuation exercise estimated that the willingness to pay of the farmers to avoid a transition to a water saving technique is INR 205.5. In the numerical exercise of the principal-agent model, simulations at the water prices of 0.2, 0.3 and 0.4 Indian rupees per cubic meter are conducted. All of these prices are below the demand price of 0.6 Indian rupees. At the water price of INR 0.2, an aggregate area allocation of 88% of the total area to water saving mode of cultivation is achieved. When the water price is increased to 0.3, all farmers in the WUA joined the contract and offered their whole farm area to the water saving mode of cultivation. The numerical simulation proved that the WUA, as principal, is able to ensure participation of farmers in the water saving contract scheme by offering a fixed initial payment, a revenue share and the bonus share and thus it achieves a maximum allocation of land to the suggested water saving mode of cultivation or irrigation by farmers. It also proves that a water price of INR 0.3 induce all farmers to switch over to water saving cultivation in response to the principal's instrument. The principal also can realise a decent remuneration for its effort.

In addition, the implication of using a bonus scheme (profit sharing) is tested by comparing its performance to a principal-agent scheme with out the profit sharing condition. The analysis shows that the contract with bonus specification achieves the maximum area allocation at a price around INR 0.3 per cubic meter, while the contract with out the bonus specification achieves it only around INR 0.45 per cubic meter and hence proving the advantage of using the bonus condition.

The numerical simulation proved that a considerable price differential exists between supply and demand prices of water. It is to be noted that the operating cost of pumps is not considered as electricity is heavily subsidised in these

regions for political gains. If we add the real operating costs also to the cost of using ground water, considerable gains of water trading becomes apparent. This proves the potential of surface water reallocation by the water rights market to Pareto optimally increase the benefits for all stakeholders in Cauvery Basin.

8.2 Political, economic and administrative viability of the water rights market

It has been proved in the preceded chapters that setting initial water rights in the Cauvery Basin is Pareto beneficial in the presence of a water rights market. In the proposed water market structure, transaction costs of defining, protecting and exchanging water rights is substantially reduced by distributing rights to water user associations (WUAs) instead of individual farmers. WUAs are allowed to generate surplus rights by coordinating water saving cultivation practices by their members using a revenue sharing contract mechanism instead of monitoring the individual water use by metering water use which has substantial transaction costs. The contract mechanism is devised to ensure that the benefit from water trade is Pareto optimal in WUAs that generates the surplus water rights for water trade. At the demand side, the possibility of buying surface water rights reduces externality of sinking groundwater tables in addition to saving high investment costs. The price differential between ground water extraction and surface water rights indicates the possible Pareto optimal benefit for the demand side. In addition, huge financial burdens of governments providing highly subsidised energy to farmers for pumping groundwater can be reduced if farmers switch over to buying additional surface water rights instead of groundwater pumping. Recall that purchasing surface water rights costs substantially less than supplementing the water deficit by groundwater pumping; even if the extraction cost (electricity charges) is fully subsidized (see section 7.4). As water buying and selling becomes a lucrative activity for farmers (via WUAs) as well as governments, settling initial water rights for the functioning of the water right markets will become politically viable. Such an arrangement can lead the Cauvery water conflict to an acceptable settlement as the final allocation of water is decided by the market and is flexible depending on the supply side and demand side conditions.

In 2002, Ballestero *et al.* suggested that there are multiple criteria or objectives for a water distribution agency and the local government; to establish a 'Market by Agencies' or MBA. Our water rights market is also an MBA, as it is operated through the water authority (See the conceptual frame of the water market in the

section 5.2.1), and hence we can check whether the proposed water market arrangement gives a feasible solution. The objectives listed by Ballestero *et al.* (2002) are: 1) Creating a market for surface water in the area under its command; 2) Protecting the historical water rights of farmers; 3) Reducing the revenue shortfall of the organization; 4) Maintaining the level of water supply; and 5) Meeting the agency's budget constraint. Regarding the first objective, it is the stated aim of the proposed water rights market. By reducing transaction costs through minimizing the individual farmer's roles in the water trade as well as by up-scaling the activities to a water user association level, the current water market model lay out the stage for effective water trading. The up-scaling is achieved by revenue sharing contracts that coordinate farmer's actions to generate surplus water rights. The incentive contract gives transparency in sharing of gains from water trade and encourages team effort in each WUA. In addition, huge costs of establishing and maintaining water meters for each and every farm are saved by limiting the quantitative allocation of water at WUA level.

Coming to the second objective, water rights allocation to individual WUAs is an important pillar of the proposed water market and hence it protects the historical water rights of farmers. Regarding the third objective, proposed market stands neutral as it neither affects nor concerned with the water fee charged by the agency to cover its operating expenses. It deals only with reallocation of water surplus generated by water saving practices. It is more so as irrigation water in the research area (also generally in developing countries) is charged at a flat rate per unit area and not per unit of water. But it can be seen that there can be substantial gains from reducing the subsidized energy provision to farmers using ground water if they turn towards buying the water saved in other WUAs. The proposed contract mechanism ensures that only the surplus water rights are sold and hence meets the fourth objective. Regarding the fifth objective, it can be expected that WUAs may take over the functions of water distribution, storage and maintenance of canals in their command area if it leads to additional water surplus and hence further gains by the trading. This new role of WUA can potentially reduce the financial burden of the distribution agency. The fair chance of WUAs taking over these activities is evident from the substantial water saving achieved in the experiments carried out by local water authorities in Cauvery Basin (see section 7.3). In addition to these, the water market in the research area can achieve objectives relevant to research area such as reducing the external costs of sinking ground water levels and decide the final allocation of the water rights as discussed in the preceded sections. In summary, establishment of the water rights market in the proposed structure has all potential to be politically, administratively and economically viable in the research area.

8.3 Efficiency, equity and sustainability in water allocation

Namboodiri *et al.*, (2006) described the ultimate goal of managing irrigation water is to ensure the efficient, equitable and sustainable water use. Equity is a major concern for the Cauvery Water tribunal as it tries to distribute water as fairly as possible among the users in each state. But during this maneuver in ensuring equitable distribution among basin states, economic efficiency takes a backseat. As explained in Chapter 4, economic consideration of water allocation dictates the political actions in the research area and hence each state tries to bargain for a higher share which often thwarts the efforts of the tribunal to set the initial water rights. It is hereby argued that if the equitable water shares allocated by the tribunal are redistributed among WUAs and the WUA rights are allowed to be traded in the interstate water market, economic efficiency can be achieved. Such a condition may lead to a change in political pay off in the water sharing issue and hence may lead to the settlement of water disputes. The attractive feature is that the final allocation of water rights is determined by market conditions rather than administrative decisions. Coming to the issue of sustainability, Namboodiri *et al.* (2006) argue that the system has to maintain the quality and quantity of water resources for the use of future generations in order to be sustainable. The water market suggested here may arrest the further deterioration of ground water availability and quality if it could generate sufficient surplus water rights to compensate the gap between extraction and recharge of ground water in WUAs which are facing a water deficit. So the proposed water market can ensure equitable and efficient water reallocation and may foster sustainable water use in the research area.

8.4 Establishment of the water rights market

Bhatia *et al.* (2006), using a computable general equilibrium model, have shown that the practice of flexible water sharing in the river basins can provide substantial economic gains in the parts of Tamil Nadu state, where a sizeable part of Cauvery river basin is located. The same can be true in Karnataka and other basin states. Bhatia *et al.* specify that a flexible water allocation system may provide 20 percent higher income, 24 per cent less water pumped from aquifers and 15 percent less overall water used by the year 2020 in Tamil Nadu state. But this paper does not answer how the flexible water sharing that reallocates water to its competing ends can be organised. The current research work lays out the water rights market model that operates at a higher scale than individual farm as a solution for this impending question.

A suggested roadmap towards establishing such a water market in the research can be summarized in the following steps: 1) Allocating the equitable water rights

to the Cauvery River basin states. The water rights allocation decision of the Cauvery water disputes tribunal can be regarded as the initial water right for the basin states. 2) Redistributing the water rights to water user associations in each state. River Boards Act in 1956 provides the provision of establishing river boards to regulate and develop the interstate rivers in request of the riparian states (Gosain and Singh, 2004). Establishment of such a river board can ensure the smooth functioning of the interstate water rights market by decoupling the regional interests from that of the whole basin. The proposed river board can take the role of the ‘water authority’ in the conceptual frame. 3) Allowing WUAs of sufficient water rights to engage in water saving contracts with farmers and sell the surplus water rights generated through the water market. 4) Allowing WUAs facing deficiency to buy water rights from the pool of water rights offered by the supply side. 5. Monitoring the results.

8.5 Possible improvisation of the visible hand

Though the option of water harvesting to generate surplus water rights in WUAs is not considered in the principal-agent scheme for evoking agent’s (farmer’s) coordinated effort (See Chapter 5), it can be easily attached to the scheme. Water harvesting in large ponds called village tanks was a custom in many of the farming areas in Cauvery basin. This tradition can be revived or can be reintroduced so that runoff during the rainy season can be collected and stored for deferred use, effectively creating surplus rights by reducing the river water demand. Traditionally such water storing structures are found in areas of water scarcity and not in areas of sufficient surface water availability for irrigation. With the presence of a water trading opportunity, one can revive the importance of water harvesting structures even in the areas with sufficient canal irrigation as they provide an additional business opportunity. If quite a number of WUAs engage in water harvesting, it may also reduce flooding of downstream area during the monsoon season.

If we add the option of water harvesting, the principal’s objective will be then

$$(19) \text{ Maximize } \sum_s [(1 - \alpha_s)(P_w h_s l_s - r_s)] + (1 - \gamma)[P_w W_T - C_T]$$

Where W_T the water is harvested by the WUA and C_T is the cost of maintaining the water harvesting system like a village tank. For making the members of WUA interested in the maintenance and use of water harvesting structures, $\frac{\gamma}{n}[P_w W_T - C_T]$ can be distributed as profit share for each farmer.

8.6 Limitations of the research work

In the study, the proof for the water rights reallocation being economically beneficial for both WUA (buyer) and WUA (seller) in both states is achieved through examining the supply and demand prices of water rights. Nevertheless, quantifying the total benefit of water reallocation using the water market mechanism in the whole Cauvery River basin is not attempted due to data and resource limitations. In addition, the current study does not examine whether reallocating saved water from agriculture to sectors such as industries and domestic use can lead to economic gains. Another issue is the possibility of collective investment in water saving technology, for instance, like maintaining lined canals, regulating field to field water drainage or purchasing laser land levelling equipments which can be added to the toolbox of WUAs in creating surplus water rights are not covered. We leave these to future studies.

German Summary (Zusammenfassung)

Hintergrund und Ziele der Forschung

Die aktuelle Studie untersucht die historischen, politischen, wirtschaftlichen und gesetzlichen Aspekte des Wasserkonfliktes am Fluss Cauvery im indischen Subkontinent und entwickelt eine wirtschaftliche Lösung für das Wasserverteilungsproblem. Im historischen Kontext beschreibt die Studie die Entwicklung des aktuellen Szenarios, in welchem der Bedarf an Wasser das zur Verfügung stehende Angebot des Flusses überschreitet. Der historische Rückblick der Entwicklung von Bewässerungssystemen im Flussbecken beginnt beim Aufbau des Cauvery *Anicut* (Wasserumleitungssystem) 200 Jahre nach Christus, durch einen frühen *Chola* König, *Karikala Cholan*, um Hochwasser des Flusses Cauvery zu regulieren. Da viele verschiedene Dynastien und Regierungen die Beckenregion des Cauvery regierten, werden ihre unterschiedlichen Einflüsse bezüglich der Entwicklung von Bewässerungssystemen im Flussbecken erwähnt. Wie sich zeigte, förderten die historischen Gegebenheiten, dass sich flussabwärts und flussaufwärts des Cauvery Beckens jeweils eigene, wasserintensive Bewirtschaftungssysteme in den verschiedenen zeitlichen Perioden entwickelten. Dieses Entwicklungsmuster hinterließ einen Konkurrenzkampf der flussaufwärts und flussabwärts bewässernden Regionen um dieselbe Ressource und führte letztendlich zum Wasserverteilungskonflikt. Die Körperschaft, *Cauvery Water Dispute Tribunal*, die geschaffen wurde, um einen Vertrag zur Wasserneuverteilung zu unterzeichnen, konnte kein abschließendes Urteil fällen, dass für alle involvierten Staaten des Wasserverteilungskonfliktes annehmbar war. Vor diesem Hintergrund betrachtet die vorliegende Studie 1) die Gründe für das Fehlen von politischem Interesse an Kooperationen in Form von Wasserverteilungsverträgen, 2) bewertet verschiedene gesetzliche, wirtschaftliche und geographische Instrumente zur Wasserverteilung und schließlich 3) entwickelt sie eine Lösung in Form eines Wassermarktes. Deshalb wird der Schwerpunkt mehr auf dem wirtschaftlichen Nutzen liegen, der vom Wasser realisiert werden kann, als auf dessen physischer Verteilung. Außerdem quantifiziert die Studie 4) die externen Effekte, die bei der Nutzung von Grundwasser als alternative Quelle für Wasser entstehen, anstatt der Entwicklung eines effizienten Systems, um das Oberflächen Wasser neu zu verteilen.

Einblicke in die Feldforschung

Die systematische Auswertung der Daten über das Cauvery Flussbecken aus sekundären Quellen ergibt sinnvolle Einsatzwerte für die vorgeschlagene Wassermarkt Lösung. Das Modell legt die Daten über Oberflächen- und Grundwasserverfügbarkeit offen. Ihr Verbrauch deutet auf einen ineffizienten

Gebrauch von Oberflächenwasser und einer zu großen Förderung von Grundwasser im Flussbecken hin. Außerdem wird offensichtlich, dass die Landwirtschaft der hauptsächliche Nutzer des Flusswassers ist. Der häusliche sowie industrielle Bedarf sind damit verglichen sehr gering. Im landwirtschaftlichen Sektor, verbraucht der Reisanbau einen Großteil des Wassers. Das liegt an der ineffizienten Bewässerungsmethode der durchgehenden Überflutung. Das betont die Notwendigkeit Institutionen aufzubauen, welche die Effizienz der Einnahmen auf der Ebene der Landwirte sowie die Effizienz auf der Ebene der Wasserverteilung im Becken fördern.

Die Daten auf Ebene der Landwirte aus der ersten Erhebung umfassen 240 Landwirte aus 24 Dörfern, 24 Blocks und 8 Cauvery Flussbecken Bezirken in Karnataka und Tamil Nadu. Die Daten legen offen wie die wirtschaftliche und technische Ineffizienz auf der systemischen (Becken) Ebene die Landwirte beeinflusst und wie die Ineffizienz der angewandten Bewässerungsmethoden der Landwirte das System beeinflusst. Die Landwirte nutzen Grundwasser als Ersatzquelle, weil durch die ineffiziente Verteilung des Oberflächenwassers die Bewässerung mit der derzeit verwendeten Technologie die Wasserbereitstellung des Flussbeckens überschreitet. Aufgrund des Fehlens eines formellen Vertrages über die Verteilung des Oberflächenwassers existieren Unsicherheiten in der zeitlichen Planung der Wassertransfers zwischen den Staaten, welche auf die Ineffizienzen der Wasseraufteilung zwischen den Landwirten zurückgeführt werden. Das führt die Landwirte wiederum dazu, Bohrungen zur Grundwasserbeförderung durchzuführen. Zusammenfassend lässt sich sagen, dass sowohl die Menge, als auch die Qualität des Bewässerungswassers dazu führen, dass das Grundwasser die bevorzugte Quelle für Bewässerungswasser der Landwirte ist. Der Ausdruck „Qualität“ des Wasserangebots bezieht sich dabei nicht auf die physikalische Qualität des Wassers, sondern mehr auf die Qualität des Verteilungssystems. Aus den primären und sekundären Datenquellen wird ersichtlich, dass die derzeitig beförderten Grundwassermengen die Grundwasserneubildung überschreiten und die Grundwasserspiegel auf einen alarmierenden Stand fallen.

Die erste Erhebung zeichnet das Bild eines landwirtschaftlichen Systems, welches von kleinen landwirtschaftlichen Betrieben (<2 ha) dominiert wird. Die Landwirte in der Studie haben ein durchschnittliches Bildungsniveau von 8 Jahren Schulbildung. Außerdem bauen sie vor allem Reis, Zuckerrohr und Hirse an und sind stets mit Unsicherheiten bezüglich der zur Vergütung stehenden Menge und Qualität des Oberflächenwasserangebots konfrontiert. Sie befördern mehr Grundwasser als zurückgebildet werden kann und setzen ineffiziente Methoden der Bewässerung ein. Sie versorgen eine Familie mit sechs Mitgliedern. Die

Landwirte ziehen Nutzen aus Krediten von formellen oder informellen Quellen, um in die Förderung des Grundwassers zu investieren, sogar bei Zinssätzen, welche die formalen Banksätze weit übersteigen.

Die Studie hat ebenso gezeigt, dass die Landwirte keine politische Partei wählen würden, welche sich bereit erklärt einen Kompromiss in der Mengenverteilung des Oberflächenwassers bezüglich der betroffenen Staaten einzugehen. Die Mehrheit der Farmer ist jedoch bereit eine Partei zu wählen, welche volle Subventionierung von elektrischen Pumpen zur Beförderung von Grundwasser verspricht.

Das Gefangenen Dilemma in der Wasserverteilung

Wasserverfügbarkeit ist der Faktor, der über die Zugehörigkeit zur sozialen Schicht des Landwirts entscheidet. Mit anderen Worten, der Zugang zu Wasser entscheidet, ob er zur Kategorie der armen Landwirte gehört, die im Pflanzenanbau abhängig von der zufälligen Regenwahrscheinlichkeit sind, oder zur Gruppe der erfolgreichen Landwirte, die einen Zugang zu Oberflächen- und/oder Grundwasser haben (oder beides). Daher hängt seine/ihre politische Entscheidung von der Strategie einer politischen Partei hinsichtlich des Zugangs zu Oberflächen- und Grundwasser zur Bewässerung ab. In diesem Szenario ist es für jede Partei am besten, Position für die Nichtkooperation im Wasserverteilungsabkommen zu beziehen, als einen Kompromiss zwischen den aktuellen oder historischen Verteilungsniveaus im Cauvery Flussbecken zuzustimmen. Diese Strategie sichert, dass die konkurrierende Partei keine übermäßigen Vorteile bei der Wahl hat, durch das Verkünden ihres nichtkooperativen Standpunkts. Die Erkenntnis aus diesem Ergebnis ist die Notwendigkeit der Entkopplung der Menge der Wasserverteilung von dem ökonomischen Gewinn, den das Wasser repräsentiert.

Ein Wassermarkt als Lösung des Wasserverteilungsproblems

Zur Entkopplung der Wasserrechte (oder zur ersten Wasserverteilung) von den Nettogewinnen die das Wasser repräsentiert, kann ein Markt für Wasserrechte eingeführt werden. Bei Bestehen eines Marktes für Wasserrechte wird die endgültige Verteilung des Wassers von Angebot und Nachfrage entschieden, auch wenn die anfängliche Verteilung durch ein Wasserverteilungsabkommen geregelt wird. Auch wenn die Lösung bereits von mehreren Forschern vorgeschlagen wurde, sind die größten Hemmnisse gegenihre Einführung die hohen Transaktionskosten des (1) Ermitteln von Erfordernissen eines funktionierenden Wassermarktes, dass heißt die Verteilung der anfänglichen Wasserrechte und die Gewährleistung, dass das Wassers zu den individuellen Feldern gelangt, (2) die

hohen Transaktionskosten einen adäquaten und willigen Käufer für individuelle Wasserrechte zu finden und (3) die damit verbundenen administrativen Kosten der Neuverteilung der Wasseransprüche. Um die Kosten der Etablierung und der Transaktion des Wassermarktes zu reduzieren, ist beabsichtigt, die Anzahl der Akteure auf dem Wassermarkt zu verkleinern, indem die Verteilungsrechte anstelle einzelnen Betrieben Gemeinschaften von Landwirten (Wasser Nutzer Verbände) zugesprochen werden. Auf einem solchen Markt können die Wasserrechte von den Wasser Nutzer Verbänden gekauft und verkauft werden.

Die unmittelbare Frage, die beantwortet werden muss, ist, wie die Koordination der Wasser Nutzer Verbände erreicht werden kann, so dass die Gemeinschaft als eine einzige Person auf dem Markt auftritt. Wenn ein Wassermarkt gegeben ist, hat jeder Wasser Nutzer Verband die Möglichkeit, wassersparende Techniken in seinem Rechtsbereich einzusetzen und den Überschuss an Rechten zu verkaufen, wenn die Preise der Wasserrechte die Kosten des Einsatzes der wassersparenden Technik ausgleichen. Die Herausforderung besteht also darin, die Nutzung von wassersparenden Techniken auf den individuellen Höfen so zu koordinieren, dass der gesammelte Wasserüberschuss gehandelt werden kann. Es wird dabei angenommen, dass die Wasser Nutzer Verbände (Verkäufer) genügend Wasserrechte zur Bewässerung ihrer Flächen mit der aktuellen Technologie aufweisen. Eine Lösung für das Problem bietet eine Einkommensteilung mittels eines Wassersparvertrags zwischen dem Wassernutzer Verband und dem einzelnen Landwirt. Die Einkommensteilung im Wassersparvertrag erfolgt über drei Instrumente zur Koordination des Verhaltens des Landwirts und nutzt ein Hauptvertreter Modell: 1) Es wird ein fester Betrag als Vorauszahlung an den Landwirt gezahlt dafür, dass er dem Vertrag beitrifft, 2) eine variable Einkommensteilung, 3) Teilung des Gewinns aus dem Wasserhandel. Die Teilung des Gewinns baut sich aus dem gesamten erwirtschafteten Wasserüberschuss auf. Daraus ergibt sich ein Anreiz, als Team zu agieren. Verglichen mit der aktuellen Wasserverteilung kann der Wasserhandel im Cauvery Becken nur dann zum Pareto optimalen Anstieg der Gewinne führen, wenn die Kosten des Einkaufs zusätzlicher Wasserrechte niedriger sind, als die Kosten, die den Wasser Nutzer Verbänden auf der Nachfrageseite entstehen für die Verwendung einer alternativen Wasserquelle, wie dem Grundwasser. Um also den Preis abzuschätzen unter welchem die Wasserrechte eine realisierbare Alternative sind, müssen die Kosten der Förderung von Grundwasser berechnet werden.

Kostenschätzung der Grundwasserförderung

Die drei Kostenkomponenten der Grundwasserförderung sind 1) Investitionskosten in Bohrbrunnen und Pumpanlagen, 2) Pumpkosten, das heißt

Elektrizitätskosten und 3) die durch externe Effekte des fallenden Grundwasserspiegels anfallenden Kosten. Die durchschnittlich zurückzuzahlenden Investmentkosten pro Hektar für den Aufbau von Bohrbrunnen betragen bei diesem Beispiel 5827 indische Rupien (INR). Weil Elektrizität stark subventioniert wird, werden die Pumpkosten auf Seiten der Landwirte nicht beachtet. Die Kosten der externen Effekte werden durch eine räumliche hedonische Regression der Wasserspiegelstände auf Landpreise geschätzt. Bei der Durchführung der räumlichen Schätzung wird ein Baye'sches Bezugssystem verwendet. Externe Effekte auf Landpreise können so explizit modelliert werden. Die Ergebnisse der hedonischen Regression ließen einen Verlust von etwa 80000 INR pro Hektar erkennen, bei einem dazugehörigen Abfall des Wasserstandes von 4 Metern bis 40 Metern. Es wurde festgestellt, dass der Wert eines Ackers an den Landpreis eines nichtbewässerten Ackers heranreicht, wenn der Wasserspiegel 40 Meter unter die Geländeoberfläche sinkt. Ein Abfall von etwa einem Fuß pro Jahr (1 Fuß = 0,3048 Meter) kann den Wert eines Ackers um 947 INR (bei einer Tiefe von 9 Metern) bis 151 INR pro Hektar (bei einer Tiefe von 43 Metern) und Jahr mindern. Der Abfall von einem Fuß (0,3048 Meter) pro Jahr aggregiert sich zu einem Abfall von 3 Metern pro Jahrzehnt. Die untersuchten Beckenbezirke werden durch den zentralen Grundwasserverband als Gebiete klassifiziert, deren Wasserstand um mehr als 2 Meter pro Jahrzehnt absinkt. Daher wird die Absenkung des Landwertes, beruhend auf einem Abfall des Wasserstandes um 0,3048 Meter, als externe Kosten pro Jahr veranschlagt. Deswegen zeigte sich auch, dass die durchschnittlichen Kosten der Nutzung des Grundwassers pro Hektar durch die Wasser Nutzer Verbände auf der Nachfrageseite etwa 6000 INR bis 7000 INR pro Hektar und Jahr betragen. Für einen durchschnittlichen Landwirt, welcher 50 Prozent seines Wassermangels für zweijährigen Reisanbau (1000 Kubikmeter/Hektar) über Förderung von Grundwasser ausgleicht, beträgt dies 0,6 INR bis 0,7 INR pro Kubikmeter. Dieser Betrag kann als Nachfragepreis nach Oberflächenwasserrechten gelten. Wenn die Preise der Oberflächenwasserrechte dieses Level überschreiten, wird die Förderung von Grundwasser die billigere Alternative.

Angebotspreis von Wasserrechten

Um zu sehen, ob eine ausreichende Preisdifferenz zwischen Angebots- und Nachfragepreisen nach Wasserrechten besteht, wurde eine empirische Simulation des Hauptvertreter-Modells zur Einkommensteilung im Wassersparvertrag durchgeführt. Die für das Modell benötigten Parameter wurden aus primären und sekundären Quellen geschätzt. Die Parameter der Kostenfunktion der Wasserspartechnik wurden durch eine Kontingente Bewertung geschätzt. Dabei

wurde eine Zahlungsbereitschaftsanalyse genutzt, um eine durchschnittliche Zahlung zu ermitteln, ab welcher die Landwirte beginnen, zur wassersparenden Methode des Anbaus zu wechseln. Die doppelt begrenzte, dichotome Anteilsbewertungsanalyse schätzte, dass die Zahlungsbereitschaft der Landwirte einen Übergang zur wassersparenden Technik 205.5 INR beträgt. In der numerischen Analyse des Hauptvertreter Modells werden Simulationen mit Wasserpreisen von 0,2 , 0,3 und 0,4 INR pro Kubikmeter durchgeführt. All diese Preise liegen unter dem Nachfragepreis von 0,6 INR. Bei einem Wasserpreis von 0,2 INR wird eine aggregierte Gebietsverteilung von 88% des gesamten Gebiets mit der wassersparenden Anbaumethode erreicht. Wenn der Wasserpreis auf 0,3 INR stieg, traten alle Landwirte dem Wasser Nutzer Verband bei und boten ihre gesamte Anbaufläche für den Anbau nach der wassersparenden Methode an. Die numerische Simulation bestätigte, dass die Wasser Nutzer Verbände als Vorsteher in der Lage sind, die Teilnahme der Landwirte am Wassersparvertrag Modell zu gewährleisten und zwar durch die Bereitstellung einer festen Zahlung zu Beginn sowie die Einkommens- und Gewinnteilung. Dadurch wird eine maximale Verteilung des Landes zur empfohlenen wassersparenden Methode des Anbaus, oder der Bewässerung durch die Landwirte erreicht. Die Studie belegt ebenso, dass ein Wasserpreis von 0,3 INR alle Landwirte dazu veranlasst, als Antwort auf das Vorsteher Instrument zum wassersparenden Anbau zu wechseln. Außerdem kann der Vorsteher eine bescheidene Belohnung für seine Bemühungen erzielen.

Zusätzlich wurden die Folgen der Nutzung eines Bonus Modells dadurch getestet, dass seine Effizienz mit der des Hauptvertreter Modells ohne Gewinnteilungsaufgabe verglichen wurde. Die Analyse zeigte, dass der Vertrag mit der Bonus Kondition die maximale Gebietsverteilung bei einem Preis von 0,3 INR pro Kubikmeter erreicht, während der Vertrag ohne die Bonus Kondition die maximale Gebietsverteilung nur bei einem Preis von 0,45 INR pro Kubikmeter erreicht und bestätigt damit die Vorteile der Verwendung einer Bonus Kondition.

Schlussfolgerungen

Die numerische Simulation belegte, dass eine beachtliche Preisdifferenz zwischen dem Angebots- und Nachfragepreis nach Wasser besteht. Es muss bemerkt werden, dass die Betriebskosten der Pumpen nicht beachtet werden, weil Elektrizität in diesen Gebieten aus politischen Gründen stark subventioniert wird. Wenn wir die tatsächlichen Betriebskosten zu den Kosten der Grundwassernutzung hinzu addieren, werden beachtliche Kosten des Wasserhandels ersichtlich. Dies belegt das Potential der Oberflächenwasser-Neuverteilung durch einen Markt für Wasserrechte zum Pareto optimalen Anstieg der Gewinne für alle Anspruchsberechtigten im Cauvery Becken.

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APPENDICES

Appendix 1: Winbugs code for the Bayesian spatial hedonic regression

```

model {
  for(i in 1:188) {
    Landprice[i] ~ dnorm(mu1[i], tau)
    mu1[i] <- alpha + beta.distroad*distroad[i]+ beta.levelwat*levelwat[i]
+beta.farmsize*farmsize[i]+ beta.soilqual[soilqual[i]]+ theta[Location[i]]
  }
# Landprice-Land price per ha

#Attributes of location
# distroad-distance to road in meters
# levelwat-level of water in meters
# Soil quality - 4 levels
# Distmarkt- Distance to market
# Determinant of Bargaining Power
# Farm size in ha
#Location
# Spatial location
# Spatial effects are explicitly modelled as land prices are spatially correlated
# Spatial area specific random effect
  theta[1:21] ~ spatial.exp(mu[], x[], y[], vr.inv, phi, kappa)

# Priors for mu
  for(j in 1:21) { mu[j] <- 0
# Priors for random effects variance
  vr.inv ~ dgamma(0.001, 0.001)
  v <- 1/sqrt(vr.inv)      # sd of spatial random effects

# Parameters of spatial exponential covariance function
  logphi ~ dunif(-12, -5.3)
# attributes correlations ranging from 0.000 to 0.940 at distance 10000 m
# and correlations ranging from 0.00 to 0.085 at distance 400,000 m
  phi <- exp(logphi)
  kappa <- 1
# prior for variance of land prices
  tau ~ dgamma(0.01, 0.01)

# vague priors on regression coefficients
  alpha ~ dnorm(0, 0.00001)
  beta.distroad~ dnorm(0, 0.00001)
  beta.levelwat ~ dnorm(0, 0.00001)
  beta.farmsize ~ dnorm(0, 0.00001)
  beta.soilqual[1] <- 0
# set coefficient for baseline soilquality to zero
  beta.soilqual[2] ~ dnorm(0, 0.00001)
  beta.soilqual[3] ~ dnorm(0, 0.00001)
  beta.soilqual[4] ~ dnorm(0, 0.00001)

```

Appendix 2 :GAMS code for the principal agent model specified in section 7.1

```

*.....
*DIMENSION DEFINITION
*.....
set J farmers /1*241/
    L year /2006/
;
*.....
*DATE ENTRY
*.....
Table land(J,L) input data for land area
*(not shown)
;
*.....
*MODEL DEFINITION
*.....
PARAMETERS
hs conversion coefficient for land to water /2000/
psi slope of cost function /20/
phi intercept of the cost function /205/
kappa reservation utility of farmer per ha /250/
Land_data(J,L) data of land area
member /241/
pricewat water price /0.2/
A total land area of WUA /565.05/
;
Land_data(J,L)=Land(J,L)
;
POSITIVE VARIABLES
alpha(J,L) share of farmer
beta share as bonus
ls(J,L) land area under contract
eta adjustment factor
;
VARIABLES
PI(J,L) principals obj
totarea total area under contract scheme
nprincipinc(J,L)
bonus(J,L) bonus offered by principal
agbonus aggregate bonus
revenue revenue
r(J,L) initial payment in water saving contract
netprincipinc Net principal income
tPI total income of principal
totrs total initial incentive
totshare total revenue share
;
EQUATIONS
qrevenue revenue of WUA
qprincipinc(J,L) principals income
qtotprincipinc gross income of principal
qincconstr incentive constraint

```

```

qnetprincipinc(J,L) principals net income
qtnetprincipinc toatl net income of principal
qpartconstr participation constraint
qlandconstr(J,L) constraint on land under contract scheme
qbonus(J,L) bonus calculation
qagbonus aggregate bonus
qtotarea total area under the contract scheme
qtotrs total rs
qtotshare total revenue share
qbeta restriction on beta
qbeta2 restriction on bet
qeta restriction on eta
qeta2 restriction on eta
;
qprincipinc(J,L).. PI(J,L)=E=(1-alpha(J,L))*(pricewat*hs*ls(J,L)-r(J,L));
qtotprincipinc.. tPI=E=sum(L,sum(J,(PI(J,L))));
qnetprincipinc(J,L).. nprincipinc(J,L)=E=(1-beta)*PI(J,L);
qtnetprincipinc.. netprincipinc=E=sum(L,sum(J,nprincipinc(J,L)));
qincconstr(J,l).. ls(J,L)=E=(alpha(J,L)*(1/psi)*pricewat*hs)-
((1/psi)*phi)+eta*(beta*(1/psi)*((totarea)/(A*A))*tPI);
qtotarea.. totarea=E=sum(L,sum(J,ls(J,L)));
qrevenue..revenue=E=totarea*hs*pricewat;
qpartconstr(J,l).. r(J,L)=E=(phi*ls(J,L))+(0.5*psi*ls(J,L)*ls(J,L))-
(alpha(J,L)*pricewat*hs*ls(J,L))-eta*(beta*ls(J,L)*((totarea)/(A*A))*tPI)+(kappa*ls(J,L));
qlandconstr(J,L).. ls(J,L)=L=Land_data(J,L);
qbeta..beta=L=0.9;
qbeta2..beta=G=0.8;
qeta..eta=L=1;
qeta2..eta=G=0;
qbonus(J,L).. bonus(J,L)=E=beta*((ls(J,L)*totarea)/(A*A))*tPI;
qagbonus.. agbonus=E=sum(J,sum(L,bonus(J,L)));
qtotrs.. totrs=E=sum(L,sum(J,r(J,L)));
qtotshare.. totshare=E=sum(L,sum(J,(alpha(J,L)*(pricewat*hs*ls(J,L)-r(J,L))));
*.....
*SOLUTION
*.....
Model princagent /all/
Solve princagent using DNLP maximizing tPI;
display
r.l,alpha.l,tPI.l,ls.l,bonus.l,beta.l,netprincipinc.l,totarea.l,totrs.l,totshare.l,agbonus.l,revenue.l,eta
.l;
*.....
TRANSFER TO EXCEL
*.....
PARAMETERS
pr paramter for r
palpha parameter for alpha
pbeta paramter for beta
pls paramter for ls
pbonus paramter for bonus
;
pr(J,L)=r.l(J,L);

```

```
palpha(J,L)=alpha.l(J,L);
pbeta=beta.l;
pls(J,L)=ls.l(J,L);
pbonus(J,L)=bonus.l(J,L);
$libinclude xldump pr bonuscontract4.xls init
$libinclude xldump palpha bonuscontract4.xls alph
$libinclude xldump pbeta bonuscontract4.xls bet
$libinclude xldump pls bonuscontract4.xls landa
$libinclude xldump pbonus bonuscontract4.xls bon
```