Methods of Valuation of Water Resources: A Review

Nilanjan Ghosh

Sr. Vice President, Takshashila Academia of Economic Research, Mumbai, India; nilanjan.ghosh@taerindia.com

Jayanta Bandyopadhyay

Professor, Centre for Development and Environment Policy, Indian Institute of Management, Kolkata; jayanta@iimcal.ac.in

---

Acknowledgements:

The authors are indebted to Mr. Satyajit Chattopadhyay and Ms. Sahana Chattopadhyay for editorial help rendered for the preparation of this paper.

==

Abstract

The valuation of water resources is extremely important from a policy perspective. Water valuation helps in efficient allocation, which often has been the prime point of contention in water resource management. Existing literature has a large number of papers on the significant attempts at valuing water. However, a number of publications only consider certain specific aspects of water pricing, rarely attempting a comprehensive review. However, such an issue cannot remain confined to disciplinary bounds. This paper presents a survey that attempts to resolve this gap by summarizing accumulated knowledge on valuation of water resources and dealing separately with valuation of water in the economic and the ecosystem sectors. Under each component, a host of studies on valuation done by various economists have been mentioned. Finally, the policy implications of water pricing have also been discussed in light of the scarcity value theory.

Keywords

Valuation, Economic Services, Ecosystem Services, Scarcity Value, Water.

==

1. Introduction

Water scarcity is on the rise in various parts of the world. Traditional modes of freshwater management are becoming defunct and obsolete. This situation calls for a paradigmatic breakthrough in the ways water has been managed so far. Over the last two decades, water valuation has emerged as an important feature for such a new paradigm and will influence policymaking in the coming years. This paper reviews the diverse approaches to the valuation of economic and ecosystem services provided by water to offer a broad platform for evaluation and policy implications to the reader. Over the centuries it has been stated that the prime problem of water systems management is with allocation. This brings in economics whose scope was delineated in its canonical definition, "… allocation of scarce resources among competing ends". A number of economists working on water have analyzed the problem of water allocation with institutional economic theories (e.g. Richards and Singh, 2001; Brown, 1997; Holden and Thobani, 1996; etc.), which, by their very nature, call for diminishing transaction costs over time. Institutionalists have talked of the economics of property rights and the legal frameworks that have been instrumental in formulating a number of international statutes on water. Analysis of the existing legal framework has been motivated by institutional thinking (Barrett, 1994). At the same time, economics of property rights has also been operational in delineating property rights explanations of water disputes (Richards and Singh, 2001; Berck and Lipow, 1994). Thus, institutional thinking has buttressed the framework for sustainable water systems management.

However, being broad and qualitative, institutional thought processes only provide some guidelines set by international and national statutes. As a result, the laws have often been too rigid to provide an easy operational solutions and, sometimes, so flexible that they could be interpreted by strong stakeholders according to their conveniences (Chauhan, 1981; Tarasofsky, 1993). Institutional economics has always talked of broad policy decisions and has only provided theoretical explanations of these decisions. At the same time, while institutionalists have been talking of the diminution of transaction costs, there has been no quantification (or monetization) of the transaction costs due to their improper delineation. This leaves the policymaker with no benchmark to ascertain the goal. Hence, institutional thinking has, so far, not proposed any tangible, neutral, and quantified instrument for water management. The above holds true for international water law, as well as for water laws for interstate rivers within national boundaries. The institutional frameworks are often without objective economic instruments despite their extensive underlying importance. The obvious question is whether it is possible to develop an instrument that can complement this broad subjective configuration provided by statutes. On the other hand, attempts have often been made to resolve interstate water disputes in a nation within the framework of the water law of the land. Even then, there is yet no domestic legal framework that makes any provision for objective evaluation of disputes. Thus, the states abide by the awards of the courts or by orders passed by the concerned bodies vested with the judicial power to take decisions on water-related issues.

1.1 Valuation as a tool

Under circumstances where institutional economics have not been able to provide an objective tool for resolution of disputes, there is the need to examine whether a more objective instrument can be developed with the help of the emerging tools for valuation. Such tools are indeed in a very early stage of development and needs to be used as an approximation. The value of a resource simply reflects the level of its usefulness to the user, whether an individual or a community, a corporate body or even a national economy. This value varies with the user. The use of valuation in water management and dispute resolution needs to be rationalised. The reasons are:

- Valuation offers a somewhat objective instrument for decision making: There often arise situations in which valuation can provide a more objective basis for decision ranking (Singh, 1994; OECD, 1995).

- Valuation aids efficient as well as equitable allocation, helps the process of proper distribution, and offers means of achieving better optimality in social consumption and production: Equity and efficiency in the allocation of natural resources have always been viewed as complementary ideas. The inherent conflicts in policy making emerge from the dichotomy between efficiency and equity. In making a policy, the value yielded by adhering to either equity or efficiency or a combination of both should be considered. Similarly with distribution. Social planners need to take into account the value of the net social welfare to decide upon the distribution scheme. At the same time, either consumption or production should be considered to optimise the net economic welfare of a system, subject to some constraints. These may exist as resource availability, infrastructural bottlenecks, economic identities, etc. Optimisation exercises yield shadow values (which reflect upon the increase in welfare with a unit release of a particular constraint). Moreover, these are extremely relevant for future decision making on economic variables (Bouhia, 2001; Mahendrarajah, 1999). Again, the valuation of eco-systemic degradations helps to devise economic instruments like pollution taxes or quantity taxes that can help in reaching social optimality in consumption or production (Acutt and Mason, 1998).

- Valuation of natural processes or resources can raise awareness of the market and the policy makers on the importance of the ecosystem or natural resource under consideration: A high value of a natural resource reflects its importance to the user(s) under consideration. Under situations where valuation mechanisms are absent, this importance remains unregistered. For example, the importance of biodiversity conservation or carbon sequestration by wetlands can be better understood if expressed in relatively quantified monetary terms. This would make a case for the public significance of wetlands when communities often fail to recognise the same (Bann, 2002; OECD, 2002).

- Valuation can help legal proceedings determine damages where a party is held liable for causing harm to another party: In legal proceedings, where one party has caused harm to another, the loss is evaluated (usually in monetary terms) and the affecter (once proved guilty) is made to compensate the affected with the value of the damage. This can also be the case for ecosystem services. Pollution from upstream areas affects the downstream ecosystems negatively. To deal with compensation policies properly, the economic value of the harm so caused needs to be assessed to obtain the extent of the negative externalities (Bann, 2002; OECD, 2002).

- Valuation helps in the designing of efficient management mechanisms (economic instruments, controls, etc.): Economic instruments like a tax or a subsidy can help in the attainment of the optimality in consumption. However, when damages due to pollution, for example, are valued, valuation opens up a range of management options (Acutt and Mason, 1998). Apart from taxes, internalisation of the externalities and governmental controls – on laying a ceiling or a floor in the associated economic activity that creates the pollution – can also help the process. Tradable permits are another option (Hanley, 1998).

- Valuation of natural processes and resources helps revise investment decisions, like in infrastructure development, that might otherwise ignore the related harm expected to be caused to the natural environment: Investment decisions on public goods and utilities (for example, roads) in many countries largely ignore the possible environmental damages, thereby causing those damages, albeit in the long run. These have adverse impacts on the natural environment and related human livelihoods. While taking investment decisions on projects, valuation of these ecological costs must be considered. It might happen that the ecological cost might be large enough to exceed the projected economic benefits from an investment, needing a revision of the investment proposal (Bann, 2002).

- Valuation reduces the scope for market failures and enhances its creation: Sometimes, there are goods for which markets do not exist. Examples are certain environmental resources, which are apparently abundant in nature, e.g. air, water, and so on. Because of non-existent markets, there is no market-clearing price. When such a resource becomes scarce, better resource management may call for the creation of markets. Valuation of the resource helps in this process of market creation (Acutt and Melinda, 1998; Fisher, 1995). This is also true for certain public goods and services. It is thus apparent that in all the major economic activities of allocation, production, distribution, and consumption, valuation can play an important role in decision-making and prioritisation. Valuation thus can offer a mechanism for extending justice and equity while setting conservation priorities within a limited budget.

1.2 Valuation in the resolution of water disputes

However, for environmental resources like water, the most important function is perhaps the correction of the market failures, which has great implications for its sustainable management. Given such a background, valuation has been proposed in this exercise as an instrument for mediating transboundary water conflicts. As a tool, valuation seems to be a more tractable one than the others. And if properly applied in the transboundary context, it can offer a more objective basis for resolving disputes. It should also be remembered that of the types of applications that have been extended from the framework of economics, valuation is the most fundamental. In game-theoretic frameworks, pay-offs to agents depend on the values they put on water. Institutional approaches subsume valuation, thereby either enabling or preventing institutions from emerging.

Water pricing, whether by government mandate or by market forces, is an important way to improve water allocations and to encourage conservation (Tsur et al., 2004) if the basic water needs of all are satisfied a priori. Interestingly, despite the realizations, there have been very few attempts at establishing an objective economic analysis of policies through this process of valuation.
For water, valuation studies have remained as isolated interests of some economists. Such studies have rarely been involved or applied effectively in the policy framework as an objective instrument for analysing and understanding water disputes. If realised properly, valuation can be an effective approach for reducing conflicts among various stakeholders by using common water resource. (Ghosh and Bandyopadhyay, 2002 and 2003; Ghosh, 2002).

A number of publications only consider certain specific aspects of water pricing with comprehensive reviews being rare. Such an issue cannot remain confined within disciplinary bounds. This survey attempts to deal with this gap by summarizing accumulated knowledge on valuation of water resources. The review finds inspiration from ecological, environmental, resource, and agricultural economics. The initiating point of the paper lies in the notion that valuation of water resources involves the valuation of the services that water provides. The paper looks at two broad aspects of valuation of water. These involve the valuation of the economic and the ecosystem services from water. The paper has been divided into four sections. Section 2 summarizes the database of the literature on economic services of water. These broadly involve the valuation of the services that water provides in the economic sectors. The studies have been broadly categorized according to the methodology and, at the next level, sectoral classifications have also been made. Section 3 discusses the valuation of the ecosystem services of water.

Finally, in section 4, an attempt is made to relate to the notion of *scarcity value* as it exists in the literature. The section also argues how the various valuation modes followed so far in academic literature has actually been valuing "scarcity".

2. Valuation of economic services of water

Depending on the way different studies treat water; these can be divided into two broad categories, namely:

- Water as an input to the production process
- Water as a good in the consumer's utility bundle

2.1. Valuation with water as an input to the production process

Contribution of water as an input to the total output occurs primarily in the agricultural and the industrial sectors. The agricultural sector is where most of the water gets used for irrigation. A large number of studies have been conducted on valuing irrigation waters with the production-function approach. The valuation of water has been reviewed keeping in mind the separate use of water in agriculture and industry.

2.1.1. Pricing of agricultural waters

While discussing the pricing of agricultural water, one must remember that the criteria for and practice of water pricing might be different. With pricing playing a fundamental role in allocation, a variety of methods for pricing water is available in the literature which can be categorized as:

- Pricing in practice
- Pricing criteria
- Valuation of agricultural water

2.1.1.1._Pricing in practice

The prevailing pricing methods include volumetric, non-volumetric, and market-based pricing methods. Under volumetric pricing mechanisms, the charge for irrigation water is based on consumption of actual amounts of water. Non-volumetric measures are based on output, input, area, and land values. The recently developed market-based mechanisms deal with the existing inefficiencies in the institutional mechanisms of allocation (Tsur et al., 2004).

- Volumetric methods: The requirement for valuing water under this method is a measure of the volume of water consumed from an irrigation system. This information is collected by an authority or water users' association, who sets the prices, monitors use and collects fees. Easter and Welsch (1986a), Small and Carruthers (1991), and Bandaragoda (1998) refer to the information requirements and costs, and the priorities to be considered. Easter and Welsch (1986b) mention the operational and institutional problems of implementing irrigational projects. Easter et al. (1997) have described temporal block-pricing methods that are followed in the varying surface irrigation charges in the state of Maharashtra in India where the water charge varies by crop and season. This implies that if the volume of water delivered per unit time by the water source diminishes throughout the cropping season, the effective price per unit of water should rise proportionally. In developed countries, with sophisticated methods for monitoring and accessing of information, multi-tiered volumetric pricing methods are in vogue. Studies by Rao (1988) on California and by Yaron (1997) in Israel reveal such examples. Boland and Whittington (2000) have traced the recent movement toward increasing block tariffs in developing countries.

- Non-volumetric methods: Non-volumetric pricing methods are used in situations where volumetric pricing is either unfeasible or undesirable. Several such pricing methods are common for irrigation service: output pricing, input pricing, area pricing, and betterment levy pricing (Johansson, 2000; Tsur et al., 2004). Area pricing is the most common mode of pricing irrigation water (Bos and Walters, 1990; Bosworth et al., 2002). Under area pricing, users are charged for water use per unit irrigated area, often depending on crop choice, extent of crop irrigation, methods of irrigation, and season. Easter and Welsch (1986a) and Easter and Tsur (1995) explain its widespread prevalence for its ease of implementation and administration, and its suitability in continuous flow irrigation. Due to the high costs of a meter system, it is often more efficient to use per unit area pricing than volumetric pricing when allocating water. However, it suffers from the practical difficulty that the area of land is assumed to be an adequate proxy for the proportion of water received. However, this may not be the case because of logistical, physical, and political reasons (Rhodes and Sampath, 1988). Under the output pricing system, farmers pay a water fee for each unit of output produced. Whereas, under input pricing, they pay for irrigation water through higher prices for inputs purchased from the government or water agency. Both input and output pricing are easy to implement since inputs and outputs are readily observable and the measurement of water used is not needed (Johansson, 2000). However, neither measure is favoured by economists because of distortions inherent in taxation (Rhodes and Sampath, 1988).

- Market-based methods: It has often been stated that market-based mechanisms can be used to reduce the inefficiencies in water allocation (Easter et al., 1999). Rosegrant and Binswanger (1994) suggest that water markets provide a flexible and efficient way to allocate water, while, at the same time, providing incentives that are beneficial for water users. When the water saved can be traded, it provides extra income to farmers, while pricing leads to a reduction in income. They also suggest that markets lead to the highest value use of water. As shown by Holland and Moore (2003) for the Central Arizona Project, a restrictive market mechanism on groundwater resources could result in ineffective solutions. According to Hearne and Easter (1995), markets should be recognized as a means to allocate water according to its real value thereby leading to efficiency gains and conservation. Gardner and Fullerton (1968), Hartman and Seastone (1970), Marino and Kemper (1999), and Holland and Moore (2003) suggest that markets can be a means to allocate water according to its opportunity cost resulting in efficiency gains. Nature of the markets can range from formal to informal. Informal water markets are found in India (Saleth, 1997), Pakistan (Bandaragoda, 1998; Meinzen-Dick, 1997), Chile (Hearne and Easter, 1997), and Mexico (Thobani, 1997). Transactions are typically small-scale and local, selling surplus water to neighbouring farmers or towns (Johansson, 2000; Bosworth et al., 2002). Formal markets involve buyable and sellable water rights, permanent and seasonal transfers or transactions between sectors and jurisdictions. Examples exist for the western U.S. (Colby, 1998) California (Howitt, 1998), Texas (Griffin, 1998), and Spain (Garrido, 1998). The most advanced form of tradable water rights are reported to exist in the Murray-Darling basin in Australia with seasonal and permanent states of diversion entitlements (Bosworth et al., 2002).

2.1.1.2. Pricing criteria

There are two broad criteria for charging a price for water. One criterion involves equity and the other involves efficiency. An efficient allocation of water resources maximizes the total net benefit that can be generated by using existing technologies and with the volumes available (Easter et al., 1997). In other words, efficiency incorporates the equalisation of marginal benefits from the use of the resource across sectors to maximize social welfare (Dinar et al., 1997; Ghosh and Bandyopadhyay, 2002 and 2003; Ghosh, 2002). Sampath (1992) describes four situations under which efficiency can be defined within the relevant time horizon. Johansson et al. (2002) adopted a similar definition of efficiency. As put by Dinar et al. (1997), in the short run, an efficient allocation maximizes net benefits over variable costs. This results in the equalisation of marginal benefits from the use of the resource across sectors to maximize social welfare. In the absence of taxes or other distortionary constraints, an allocation that maximizes net benefits is called *first-best efficient* or *Pareto efficient* (Tsur et al., 2004; Johansson et al., 2002). With the incorporation of long-run fixed costs in the short-run maximisation problem, Pareto efficient allocations are possible. However, when maximization occurs under distortionary constraints, the allocation is termed *second-best efficient* (Mascollel et al., 1995; Tsur and Dinar, 1997; Johansson, 2000).

Equity of water allocation is concerned with "fairness" of allocation across economically disparate groups in society, and often, this turns out to be incompatible with efficiency objectives (Seagraves and Easter, 1983; Dinar et al., 1997; Dinar and Subramanian, 1997). As suggested by Sen (1973), the concept of "fairness in allocation" is vague and amorphous, and hence, subjective in nature. Therefore, it is essential to obtain a yardstick to measure fairness. Sampath (1990) uses a *Rawlsian* concept of fairness to investigate equity in India's irrigation systems. The concept seeks to maximize the welfare of the society's least well-off individuals and allows evaluation of reform strategies in these terms. According to Tsur and Dinar (1995), water pricing mechanisms are not very effective in redistributing income. However, it always remains in the government's national interest to increase water available for certain sectors and citizens. Hence, certain sectors of the economy (e.g. agriculture) are offered water at subsidised rates. This is where inefficiency often creeps in. To analyze such issues, Seckler et al. (1988) differentiates between the evaluation of an irrigation system – considering efficiency as a managerial issue – and the other, a policy.

Pricing can be an effective tool for both equity and efficiency under certain conditions. Differential pricing based on volume, as stated in *volumetric methods,* is based on the notion of vertical equity. On the other hand, market-based pricing is more likely to produce efficiency. When left to market forces, water tends to find a value of its own. The market price of the resource bears the signal of the level of its availability and scarcity. A higher market price of water would reflect on a higher effective demand for water. With water finding its value in the market, a trend toward greater efficiency is seen.

For the variants from equity and efficiency, non-volumetric prices might apply. This is particularly true for output pricing. Under output pricing, it is assumed that a higher output entails a higher use of water. It thus loses its visions thoroughly from the efficiency notions of resource-use efficiency and factor productivity. Output pricing can result in an individual getting unnecessarily penalised despite lower exploitation of the resource.

2.1.1.3. Valuation of agricultural waters

Attempts by environmental and agricultural economists to obtain the value of water exist in reasonable numbers. In a majority of cases, agricultural water has been valued with a production-function approach. This involves assuming a production function where water is an input in the production process. Theoretical details of the economic principles based on which such pricing, and hence, the demand and supply curves for water can be derived, have been provided by Tsur et al. (2004: 64-85). Similar to economic valuations in various contexts over time and space, assigning a monetary value to water through improved agricultural output, resulting from improved availability of resources, involves what has popularly been termed a with-versus-without comparison (Gittinger, 1982).

Bouhia (2001) provides a value of water from a constrained maximization exercise on Morocco. This study stands as one of the most comprehensive ones in structure and content. The analysis talks of the sectoral shadow values of water by considering the three sectors, namely industrial, urban, and agricultural. Ghosh and Bandyopadhyay (2002), in a theoretical yet simplistic mode, propound static and dynamic frameworks to set the rules for optimal payment that the beneficiaries should pay the affected for obtaining benefits from a marginal increase in water usage. They (Ghosh and Bandyopadhyay, 2003) suggest similar exercises in the upstream-downstream framework. All these exercises talk of the shadow value of water that emerges from the value of the multiplier associated with the optimization exercise.

Barring a few (some of which have been mentioned above), most of the studies have been confined to the sectoral allocation of water. Of the publications on the agricultural shadow values, those by Acharya (1998) and Kumar et al. (2003), are recent. Young (1996) suggests applied approaches that incorporate change in net income – the most commonly used method of determining the shadow price of irrigation water. Omezzine et al. (1998) have taken the average returns to water from agriculture and set the path to the approach to valuation. Among the examples of economic analysis of irrigation, issues using a mathematical programming approach are a study by Bernardo et al. (1987) in which a programming model was developed and applied to assess irrigation management decisions in the north western United States. The researchers identified various responses to growing water scarcity and rising energy costs, including more careful irrigation scheduling, crop substitution, the adoption of irrigation labour practices, and the idling of land. Mahendrarajah (1999) uses the latest optimization tools and simulation models in his study on small-scale water resource systems in Sri Lanka. Gomez-Limon and Riesgo (2004) have developed Multi-Attribute Utility Theory (MAUT) mathematical programming models that reveal the usefulness of differential analysis in evaluating the impact of a water-pricing policy. This was applied in the case of Duero Valley in Spain. This allows one to observe significant differences in the evolution of agricultural incomes, the recovery of costs by the state, demand for agricultural employment, and the consumption of agrochemicals resulting from rising prices of irrigation water in various groups of farmers within a given irrigated area.

Lindgren (1999) used field-based primary data with residual valuation method for the evaluation of Stampriet aquifer of Namibia. Existing literature points out that residual imputation is valid if two conditions are satisfied (Young, 1996, Southgate, 2000). First, all inputs and outputs must be exchanged in markets that are both competitive and unregulated. On the factor side, this means that the price of each and every input is equal to its marginal value product (i.e. output price multiplied by the additional output associated with a marginal increase in employment of the factor). Second, the production function should be so that an X-fold increase in each and every input leads exactly to an X-fold increase in output (Southgate, 2000). However, Lindgren (1999) hardly makes such assumptions explicitly, and generates the value with a small sample of 17 farmers from the questionnaire method, which also raises questions on the data and the estimates.

In India, quite a few economists have, however, worked extensively on detailed analysis of economic contributions from irrigation and related agricultural production. An impressive amount of literature is available on this subject and Vaidyanathan (1999) has given a realistic picture of economics of irrigation in India. The water sector suffers from economic ills of under utilization, inequitable distribution, heavy loss of stored water, and so on, but their quantification and subsequent use in policy have not happened. Interestingly, research on more advanced topics, for instance, pricing of water, and allocation under conditions of physical scarcity, has not entered the decision-support arena.

That has not deterred scholars though. There have been quite a few studies that have unanimously indicated that the prevailing irrigation water rate for different crops in India neither promotes use efficiency nor cost recovery (e.g. Vaidyanathan, 1994; Sangal, 1991; MoWR, 2002; Nagaraj et al., 2003; Ghosh, 2005. Vaidyanathan (1994) classified three major heads of cost of irrigation water, namely operations and maintenance, depreciation, and interest on capital invested. Nagaraj et al. by considering the same three heads, revealed the yawning gap between revenue collected and expenditure incurred for various crops. The gap persists, and the problem related to cost recovery has mostly been attributed to the political economy of the water sector in India (Vaidyanathan, 1999). In a recent essay, Vaidyanathan (2004) discusses the issue of water charges and suggests a two-pronged strategy: involving the media to highlight the current mismanagement of irrigation, and utilising farmers' awareness of the improved water management to mobilize their support for better maintenance by operation and maintenance (O & M) cost recovery. While this is a good beginning, there is no doubt that the political economy of water pricing is complex and made even more complicated by the vote-bank politics (Mollinga, 2003; Gulati et al., 2005). Somanathan and Ravindranath (2006) argue that raising the marginal price of electricity toward its actual cost could substantially mitigate the problem of over-extraction of groundwater. They have arrived at this conclusion with the help of a survey estimating the value of water, and arriving at a structure for demand functions. Ghosh and Bandyopadhyay (forthcoming) have also discussed the political economy of conflicts in the Cauvery basin, and have attributed conflicts to non-diminishing scarcity value of water from paddy cultivation in the basin, resulting in an "insatiable demand".

2.1.2. Pricing of water as an input in the industrial sector

The value of water in the industrial sector emerges from its role as an intermediate public good that plays an active part in production processes thereby reducing the unit cost of production. Despite the ubiquity of water use among manufacturing firms, studies concerned with the structure of industrial water demand are few. A majority of the water-use studies for industry were performed by estimating water demand models where the ratios of total expenditures to total quantity purchased were used as proxies for prices. The initial studies of water use in the industry were conducted by estimating single-equation water-demand models where the ratio of total expenditures to total quantity purchased was used as a proxy for price (Turnoskvsky, 1969; Rees, 1969; DeRooy, 1974). Grebenstein (1979) and Babin et al. (1982) extended these analyses to incorporate trans-log cost functions where water was being included and treated like any other input as labour, capital, and materials, and the average cost of water is used to determine the price. Most of these studies used average cost of water as an indicator of price. Thompson and Singleton (1986), Renzetti (1992) and a few others on recent counts (e.g. Dupont and Renzetti, 2001; Reynaud, 2003) have used either econometric or programming methods to examine the structure of industrial water demands. Renzetti (1988) assumed a Cobb-Douglas production function to derive a water-demand function in estimating industrial water-use elasticity. He used firm level data on water use and expenditures for British Columbia manufacturing firms in 1981. In another paper, Renzetti (1992) reports the general findings, suggesting that water demand was inelastic.

In most jurisdictions, self-supplied firms typically obtain their raw water intakes at little or no external cost (Renzetti and Dupont, 2003). In these cases, analysts typically have access to information on the quantity of water withdrawn, and perhaps, the firms' characteristics. A number of methods have been employed for inferring the value of industrial water use in these circumstances. One straightforward method involves calculating the ratio of the value of output to the quantity of intake water (Giuliano and Spaziani, 1985; Mody, 1997). This approach is problematic as it fails to account for the contributions to production of non-water inputs and for differences in revenue across firms that are not related to water use, such as the structure of output markets.

A variation on the above approach is adopted by Wang and Lall (1999). They developed a marginal-productivity approach for valuing industrial use of water and applied it by using data from 2,000 industrial firms in China, where water as well as capital, labour, energy and raw materials is treated as an input to a production function. The authors have regressed total revenue against input quantities and a set of regional and scale dummies by using data from a cross-section of Chinese manufacturing plants. On more recent accounts, Goldar (2003) has worked on water use and its value in the Indian industry with econometric fittings. Prior to that, Goldar and Pandey (2001) have studied the distilleries in India and have worked out their pricing and abatement cost of pollution. The paper also exhibits how in countries like India, where concentration-based environmental standards are adopted for water pollutants and financial-extraction costs of water are too low, firms have incentives to dilute the effluent stream with the excessive use of water. Kumar (2006) has used input distance function to estimate industrial water demand in India with a linear programming approach on a sample of 92 firms over three years. The results show that the average shadow price of water is Rs 7.21 per kiloliter and the price elasticity of derived demand for water is high – 1.11 on average – a value similar to what has been found by other researchers working on developing countries (for example, China and Brazil). This indicates that water charges can be an effective instrument for water conservation. Holmes (1988) and Renzetti (2001) estimate econometric models which demonstrate that water treatment plant costs rise with decreases in water quality.

Gibbons (1986) reports on the use of linear programming models to base valuation measures on the marginal cost of recirculation and concludes that the values are typically quite low: $6–10/acre-foot (1980 US$) for cooling water and $16 to $75/acre-foot for process water applications. According to Renzetti and Dupont (2003), such methods are useful when data on water prices and quantities are not available. Under conditions of regulatory restrictions that restrict the firms' freedom to alter intake water quantities, estimation of a restricted cost or profit function in which water is treated as a quasi-fixed input, as conducted by Halvorsen and Smith, (1984 and 1986) is suggested. The estimated cost or profit function coefficients can then be used to calculate the shadow values for water.

2.2. Valuation of water as a good in the utility bundle if the consumers

Valuation of water as a good in the consumers' utility bundle has followed three approaches. These can be classified under two broad heads: the stated preference approach and revealed preference approach. Stated preference approach has only one component, which is popularly known as Contingent Valuation Method (CVM). This method involves the creation of a hypothetical market and by asking respondents about their willingness to pay for a change in their ambient environment, qualitative or quantitative (Mitchell and Carson, 1989; Kolstad, 1999). Under revealed preference approach, there are two categories, namely Travel Cost Method and Hedonic Pricing Method. Travel Cost Method estimates the value of an environmental resource through the amount spent by a consumer in visiting that resource. On the other hand, Hedonic Pricing estimates the value of a resource through the differentials in the property prices resulting from variations in ambient environments through location changes (Kolstad, 1999). Applications of such methods can be found in limited numbers for irrigation waters, in greater abundance for urban waters and in various non-use values of water.

2.2.1. Pricing of irrigation water as a good in the utility bundle of the consumers

Irrigation water has rarely been priced as a good in the consumer's utility bundle. Contingent valuation has not been used very frequently in the study of water for irrigation. The same can be said about Travel Cost Methods. The seemingly apparent inapplicability of such methods in valuing irrigation water (where water is always to be seen as the input in the production process) has perhaps restrained research with these methods.

However, Hedonic Pricing perhaps seems to be one that can be applied in this case, though in a restricted manner. This has been used in *ex post* evaluations of irrigation projects and usually involves analysis of agricultural real estate values. An econometric model relating these values to all relevant variables is estimated. Of particular interest are the price differentials between irrigated and non-irrigated land with allowance for other factors influencing the market value of real estate like location and soil quality (Southgate, 2000). In the late 1980s, for example, Whitaker and Alzamora (1990) conducted a survey of real estate values to determine the premium offered for irrigated land in Ecuador. Their sample included parcels lying inside systems that account for three-fifths of the irrigable area of the country's government-run projects. Price data for similar parcels, close to but outside those same systems, were also collected. Per-hectare premiums were found to range from $367 to $3,897. The weighted average for 25 projects was $1,091 per hectare, which was a little less than half the average cost of irrigating that same land. That is, *ex post* evaluation revealed that irrigation investment in Ecuador had turned out to be quite inefficient.

2.2.2. Pricing of water supply to urban areas

The Contingent Valuation Method can be used to estimate the consumers' willingness-to-pay (WTP) for just about any environmental good or service, including clean water. Whittington (1991) and Whittington et al. (1993) have carried out contingent valuation studies of the WTP of households for improved sanitation services. The same approach can be used in potable water valuation. Whittington et al. (1990) have estimated the WTP of the consumers for water services in a case study in southern Haiti. Jordan and Elnagheeb (1993) have examined the WTP for improvements in drinking water quality. Ragan et al. (1993) provide estimates of the damages from residential use of mineralized water. Dasgupta (2003) uses contingent valuation methods for evaluating safe water supplies for urban households in Delhi. Esrey et al. (1991) have talked of the effects of improved water supply and sanitation on various diseases like ascariasis, diarrhoea, etc.

Musser et al. (2003) discuss contingent valuation methods as providing useful information for resolving disputes related to drinking water. Altaf and Hughes (1994) also conducted another Contingent Valuation Study for measuring the demand for improved urban sanitation services in Ouagadougou, Burkina Faso. Stewart’s (1996) study on the valuation of Sierra Nevada is one of the most comprehensive ones, and deserves mention in discussions on urban water valuation. Harris and Tate (2002) present a detailed analysis of the economic aspects of municipal-water servicing. The report initially reviews some of the economic theories related to water management, and then describes water quantity and quality issues in Ontario, closing with selected estimates of pollution related costs to water utilities. Billings and Day (1989) and Billings and Jones (1996) have long been talking of the factors affecting urban water demand, and eventually, of frameworks for forecasting urban water demand. Pricing of urban water often involved block rates in several places of the world (Harris and Tate, 2002). Billings and Agthe (1980a, 1980b) have shown the methodologies and discussed the issues involved with price elasticities of water under increasing block rates.

3. Valuation of ecosystem services of water

In recent years, the services provided by the natural ecosystems have interested economists, independent of their values in traditional economics. While the ecologists and professionals working in the area have been identifying the list of services provided by the ecosystem over time (e.g. Holdren and Ehrlich, 1974; Ehrlich and Ehrlich, 1981), there remains a lot to be done. Despite the extensive interests generated worldwide, the contributions of water as an input in the sustenance of diverse natural ecosystems have not been properly appreciated. As a result, the identification and recognition of ecosystem services by water still remains an emerging area of research. In this context, what is often missing is the understanding that provision of environmental water allocation or environment flow requirements means striking a balance between allocating water for direct human use (e.g. for agriculture, power generation, domestic supplies, industry, etc.) and indirect human use (maintenance of ecosystem goods and services) (Acreman, 1998; Smakhtin et al., 2004). With increasing diversion of water from the natural aquatic systems, striking a balance between the needs of the aquatic environment and the needs for diversion of water is becoming critical in many river basins of the world (Postel et al., 1996; Vörösmarty et al., 2000; Naiman et al., 2002). The Millennium Ecosystems Assessment has further stressed the need for the valuation of ecosystem services for water (Aylward et al., 2005). While, in general, the ecosystem services provided by water hardly gets recognized in the reductionist visions of policy making, policymakers in the developed world have slowly realized the extensive value that ecosystem services can provide.

One of the initial attempts discussing economic valuation of ecosystem services was *Proposed Practices for Economic Analysis of River Basin Projects* by the Committee on Water Resources in 1958 (Bingham et al., 1995). Valuation of ecosystem continued throughout the next decades (de Groot et al., 2002), but the focus of research has expanded greatly since two publications helped the subject gain popularity. The first is a book, edited by Daily (1997), which discusses ecosystem services, their valuation, and provides several case studies. The second is a paper by Costanza et al. (1997), which came up with a value of $33 trillion for ecosystem services across the globe by extrapolating with previous and new data. Though their methods and result were criticized, the papers served their purpose by drawing attention to and provoking discussion on ecosystem service valuation.

3.1. Ecosystem services provided by water

Ecosystem services provided by water involve the aquatic ecosystems, such as rivers, wetlands, estuaries, and near-coast marine ecosystems, from which people receive a great variety of benefits. These benefits are provided for both goods and services. Under 'goods', Dyson et al. (2003) include clean drinking water, fish and fibre, while under 'services', the components are water purification, flood mitigation, and recreational opportunities. Rivers and other aquatic ecosystems need water and other inputs like debris and sediment to stay healthy and provide benefits to people. Environmental flows are vital for the health of these ecosystems (Dyson et al., 2003). Unavailability of these flows injures the entire aquatic ecosystem, and thus, deprives the people and communities who depend on it. What stands as a danger in the long run is that the long-term absence of environmental flows puts at risk the very existence of dependent ecosystems, and therefore, the lives, livelihood, and security of dependent communities and industries.

Existing literature clearly reveals that quantitative knowledge of changes in ecosystem functions does not exist in as much detail as required. Without knowledge getting ubiquitous over time and without the development of user-friendly procedures to quantify ecosystem services, the interdisciplinary knowledge on water systems and practice of integrated water resources management will remain inhibited. One important process on which attempts for quantified modelling have been made is that of the self-purification potential of the river flows. The load of agricultural nutrients on aquatic ecosystems has increased considerably during the last few decades. This puts an extra load on the potential for self purification available in river flows (Mitsch and Gosselink, 2000). Thus, in studies on ecosystem services, the self-purification potential is frequently evaluated (Bystrom, 2000 and 1998; Gren et al., 1997).

Dyson et al. (2003) discuss various methods for defining water requirements needed to maintain the ecological processes. The same has previously been set by Dunbar et al. (1998). Tharme (1996) and Arthington et al. (1998) provide reviews of these methods. Smakhtin et al. (2004), in a seminal attempt, summarizes the results of the pilot study on global assessment of the total volumes of water required for such purposes in the river basins of the world. These volumes are referred to as *Environmental Flows Requirements* (EFR).

Previous studies on environmental water requirements have used purely hydrological methods, which derive environmentally acceptable flows from the traditional hydrological point of view and use limited ecological information or the eco-hydrological knowledge base (e.g. Richter et al., 1997; Hughes and Münster, 2000) to multidisciplinary, comprehensive methods like functional analysis, involving expert panel discussions and collection of significant amounts of geo-morphological and ecological data (e.g. Arthington et al., 1998; King and Louw, 1998).

3.2. **Economic valuation of ecosystem services of water**

One of the most comprehensive reviews of literature on economic valuation of the ecosystem services of water has been done by Dalton and Cobourn (2003). The existing body of literature on such issues needs to be seen under three heads: the theory behind ecosystem service valuation, application of ecosystem service valuation, and multifunctional attributes of agriculture and ecosystems valuation. This classification continues in the work of Dalton and Cobourn (2003). The theoretical approach for the valuation of ecosystem services is, by far, the largest section of the review because the bulk of the work on ecosystem valuation has been theoretical or analytical. However, attempts to empirically value ecosystems services have been limited in number. On the other hand, studies on ecosystem service valuation in areas such as the measurement of the multifunctional attributes of agriculture provide a contrasting view of how to expand the value of agricultural production into food and functional values.

3.2.1. Theory of valuation of ecosystem services

Despite movements toward collaborative research at the interface of environmental sciences and economic sciences, the differences in delineations of structures and contents of the two disciplines of environment and economics often act as impediments in transcending disciplinary boundaries. However, the value of ecosystem services can be a useful guide when distinguishing and measuring trade-offs between society and the rest of nature are possible and where they can be made to enhance human welfare in a sustainable manner. While win-win opportunities for human activities within the environment may exist, they also appear to be increasingly scarce in a 'full' global ecological-economic system. This makes valuation all the more essential for guiding future human activity. Farber et al. (2002), while talking of economic valuation versus ecological valuation, feel that while economics talks of values in various terms like use, exchange, labour, utility, scarcity, etc., ecology relies on energy theory of value. The paper discusses critical zones or threshold conditions for ecosystems-nonlinear relationship. This leads to the idea that there is an insurance premium that society could pay to avoid a natural catastrophe. In another paper, Limburg et al. (2002), distinguishing between the ecological modes of valuation and economic valuation, suggest that as an ecosystem approaches a state of rapid bifurcation (non-marginality), ecological methods of valuation are more appropriate than economic valuation. This suggests a combined system based on both forms of valuation, depending on where the system is for its marginality.

Bockstael et al. (2000) state that value must be stated in comparative terms – the answer to a question should involve two clearly defined alternatives. "Compensation measures cannot be defined in isolation. They are entirely dependent on the context and may change as there is change in one or more elements of that context" (Bockstael et al., 2000: 1385)]. Therefore, the need to be specific about both the default and changed situation arises.

Hannon (2001) attempts to model the ecological and economic systems into an "input-output" framework. He assumes that the system is static, linear, and requires a system-equilibrium assumption. However, he does not discuss computation of biological costs. The three core competencies of this paper are delineation of metabolism as net input of the ecosystem, use of economic techniques to evaluate metabolic costs, and addition of lost capital to the net output definition to determine the system efficiency.

Alexander et al. (1998) assume "weak complementarity" that implies that ecological services are absolutely essential in production and consumption – their value can be as much as the surplus generated in all production and consumption processes. In an interesting discussion, Wilson and Howarth (2002) proposes that valuation of ecosystem services should be elicited through free and open public debate to enhance the social equity of the final decision, in contrast to other methods that rely on individual estimates of WTP or WTA. Farber and Griner (2000), in a critical attempt to value ecosystem change using conjoint analysis, feel that the methodology is more appropriate for ecosystem valuation than any other because it allows the valuation of "complex multi-attribute values to people" (Farber and Griner, 2000: 1408). Eventually, they have shown its application in a watershed quality study. However, later on, there have hardly been attempts to evaluate environmental change with this methodology, maybe because of the difficulty of administration and understanding.

Kaiser and Roumasset (2002) estimate the value of indirect ecosystem services that do not contribute to the production of a well-valued final good (e.g. public goods) in their study on valuing tropical wetlands by using shadow prices, calculated from an optimizing model to estimate the discounted net present value of water resources with a conservation policy and without the conservation policy, respectively. Their economic model involves consumer surplus formulation.

Some other notable attempts on the theoretical approach to valuation of the ecosystem services have been those by Antle and Capalbo (2002), Ando et al. (1998), Hawkins (2003), Simpson (2001), and many others. Antle and Capalbo (2002) demonstrate the limitations of using economic-decision models that are not integrated with biophysical processes by using an example from Ecuador.

Simpson (2001), while delineating a conceptual framework, expresses that the data with which to implement them empirically is generally not available. Conceptual frameworks in these lines have also been developed by Ghosh and Bandyopadhyay (2003). Ghosh and Shylajan (2005) posed a theoretical model of stream-flow depletion and pollution affecting the mangroves and fisheries negatively, and they, eventually, propounded a principle based on which "compensation" can be paid to the fishermen. There is no doubt that theoretical models have their own novelties, but what constrains their real-life applications is the understanding of the complex ecological processes, which further acts as an impediment for data availability. Resultantly, the theoretical models have often been incomplete, and could have been improved even in theoretical terms to incorporate greater ecological functions.

3.2.2. Application of ecosystem service valuation

Research on the application of ecosystem service valuation has, indeed, been limited for the obvious reasons stated above. At the same time, the few that has happened have been criticized on various methodological grounds. Klauer (2000), based on an analogy between the ecological and economic systems, uses mathematical economic price theory and applies it to ecosystems to derive values based on gross ecosystem outputs. It has been inferred from this study that estimated prices are not comparable to economic prices because neither are there any relation to individual evaluations nor are they comparable over time (and structural changes). Flessa (2004) estimates that ecosystem service value of the Colorado water is $208 per acre-foot ($0.17 per cubic metre). He thus concludes that the ecosystem cost of $208 per acre-foot ($0.17 per m3) is a hidden subsidy currently paid through the loss of nature's services to society. Lazo (2002) presents a comprehensive delineation of the valuation of ecosystems and provides an overview of methods for the valuation of ecosystem services. The study uses methods from non-market valuation to scale potential restoration projects.

However, the paper that has been the most referred as well as the most criticized in this purview is that by Costanza et al. (1997). They have compiled more than 100 studies that estimate the ecosystem services of various biomes. Then, they have obtained the values of these services using one of three methods: the sum of consumer and producer surplus, producer surplus, and product of price and quantity. They multiply these values by the surface area of each respective biome to generate an estimate of the total value of all ecosystem services. They estimate the total value to be in the range of $16–$54 trillion. Pearce (1998), in a critique of Costanza et al.'s paper, expresses that the latter have violated all principles of economic valuation. The results are inconsistent with WTP as the estimates ($33 trillion) exceed world income. They focus only on benefits of protecting environment, not costs. They do not conduct a marginal analysis, and "find the value of everything", but WTP is for relatively small changes, not the extensive changes that Costanza and his co-authors assume. The paper has also been criticized on methodological grounds, especially with the assumption that there are no irreversible environmental thresholds, and there is no interaction between services (Dalton and Cobourn, 2003).

One of the comprehensive publications by Chopra et al. (2003) has devoted a substantial portion to ecosystems services valuation in the Indian context. Moreover, in policy response options on the linkages between ecosystem and human well-being, Chopra et al. (2005) have emphasised the urgent need for valuation of the development environment linkages.

The other notable studies are summarized in table 1.

Table 1: Some notable studies on the valuation of ecosystem services of water

Author	Methodology Classification	Summary
Kaplowitz (2000)	Contingent valuatio methods	Empirical test of the use of focus groups versus individu interviews to identify and value ecosystem goods. Examir hypothesis that focus groups and individual interviews, all el being equal, "reveal similar sets of information about a share mangrove ecosystem" (171).
Kerr (2002)	Informal person interview	Looks at watershed development projects initiated in India und various types of organizations and qualitatively analyzes th impact of those projects on the poorest sector of societ Women and the poorest in the villages were hurt the mos where public lands are closed to use for revegetation.

Chomitz et al. (1998)	Analysis of financing Environmental services	Details particulars of Costa Rican federal programme for fo forest benefits: biodiversity, carbon sequestration, watershe protection, ecotourism, and scenic values.
Kumar et al. (2003)	Production function approaches	Evaluates groundwater recharge through the agricultur production in the floodplains of the Yamuna river in th corridors of Delhi.
Pan et (2002)	Ecological functio analysis and indire valuation methods	Attempted to estimate the Baoan lake ecosystem services (CO fixation, O_2 release, nutrient recycling, water conservancy ar water supply and SO_2 degradation) and its indirect econom values on the basis of ecological function analysis and econom methods.
Sekar (2003)	Contingent valuatio methods and hedon pricing methods	Conducted for Kargambathur village of Vellore district in th state of Tamil Nadu in India to assess the effects of deterioratio of the Palar river due to pollution from the leather industry.

3.2.3. Multifunctional attributes of agriculture and ecosystems valuation

It is often difficult to distinguish between the studies mentioned in the previous section discussing the application of ecosystem service valuation and the category delineating the multifunctional attributes of agriculture and ecosystems valuation, because both are mere applications. However, this sub-section takes into its fold the various attributes of agriculture to value the ecosystem services of water. Although agriculture's primary function is the production of food and other commodities, it is also the source of many non-commodity outputs. Most agricultural commodities are traded on well-organized markets. In contrast, most non-commodity outputs, such as food safety, contributions to the environment, landscape amenities, and cultural heritage are not traded on such markets. Despite this, non-commodity outputs are clearly valued by the inhabitants of rich countries, and that valuation appears to increase as their incomes and wealth rise (Blandford and Boisvert, 2004).

Chopra and Adhikari (2004) have attempted to model the development-environment linkage in a simulation framework. They have formally brought out that supply of ecological resources are determined by technological, physical, and ecological factors, while a series of behavioural and institutional variables have an impact on the demand for such services. The methodological problems in such attempts might be numerous. However, both the interests of ecologists and economists have been reconciled in this paper by investigating the nature of linkage between the economic value and the ecological value in Kaoladeo National Park.

The existing strands of literature reveals the prevalence of interesting methods of obtaining value of the watersheds ecosystems under this head. Some of the more popular methods include producer surplus approaches, dynamic programming models, and contingent valuation methods. A few studies under this head have been summarized in table 2.

Table 2: Studies on the multifunctional attributes of agriculture and ecosystems valuation

Author	Methodology Classification	Summary
Pattanayak and Kramer (2001)	Producer Surplus Approach	They have generated estimates of the value of forested watersheds in terms of drought mitigation by estimating the impact of a change in base-flow on agricultural profit through increased production of coffee and rice.
Portela and Rademacher (2001)	Dynamic Programming and Simulation	Examine four ecosystem services in Brazilian Amazonia's river drainage basin, including climate regulation, erosion control, nutrient cycling, and species diversity. Use estimates from Costanza, et al. to value the four services.
Smith et al. (1998)	Contingent Valuation Method	Look at the possibility that small-scale farmers in Peruvian Amazon could provide carbon sequestration services. Taxation is considered an undesirable alternative because of equity considerations and enforcement difficulties.
Peterson et al. (2002)	Commentary on the Policy Perspective	For an open economy, output subsidy is only efficient if all multi-goods have positive social values, and production of non-commodity outputs is fixed in proportion to production of commodity outputs. Decoupled policies only work if every input can be allocated separately in the production of either public or private goods.
Babcock et al. (1997)	Commentary on Valuation Tools	Examines implications of using alternative decision rules that do not maximize total environmental benefits (cost, benefits, and C/B ratio targeting). Infer that Benefit Ranking is superior to Cost Ranking, in most cases.
Horan et al. (1999)	Commentary on the effects of Valuation	Literature deals with economic efficiency and gives no weight to farm income objectives that are important in designing a green payments programme.
Helfand and House (1995)	Production Function Approach	Estimates the losses due to the use of second-best regulatory instruments when pollution sources vary in characteristics, as applied to lettuce production in California's Salinas Valley.
Randall (2002)	On Valuation Methodologies	A commentary stressing the need for right valuation to remove inefficiency.

4. On the notion of "scarcity value" of services

"Scarcity Value" of services as an environmental resource has remained a neglected concept, with its implicit and infrequent mention in the literature. Values arise due to the shortages of the resource under consideration and act as a monetised scarcity signal (Batabyal et al., 2003). Though Batabyal et al. (2003) are the initial ones to explicitly realise that there are differences between total value and the value of scarcity, the concept of the implicit allusions of scarcity value can be found in the concept of Ricardian rent (see Ricardo, 1817) where rent increases because inferior quality of land is

being brought into the fold of the production process, resulting in diminishing productivity of the marginal land. However, existing literature has hardly recognised this phenomenon.

Despite that, ever since the time of Ricardo and Malthus, economists have explicitly discussed the concept of the scarcity of economic resources. The basic economic resources turned out to be natural endowments (e.g. land, water, forest, etc.). Such environmental resources are becoming scarce over time with the swiftness of human consumption, and the typical irreversibility thereof on a time scale of interest to humanity warrants substantial prudence in human predatory behaviour (Daily, 1997; Daily et al., 2000). While the concept of scarcity implicitly remained in the analysis of the classicists and neo-classicists and never came to the forefront, it was finally formalised by Hotelling (1931). Hotelling showed the mechanism by which a market price serves as a signal of scarcity. Interestingly, though it was not explicitly present in the works of other market economists, it remained dormant in their analysis. Barnett and Morse (1963) extended this work by demonstrating the way in which the increasing price associated with increased scarcity actually mitigates the scarcity problem.

However, in all these works on scarcity, the focus has primarily been on the scarcity of the exhaustible resources for which well-functioning markets exist. Environmental resources are non-market goods; hence, the market system has no say in their price determination. Therefore, there is no readily available price or non-price signal that can serve as an indicator of scarcity. Costanza and Folke (1997) and Goulder and Kennedy (1997) point out that important ecological phenomena that affect the scarcity of ecosystem services are often not incorporated into prices. Batabyal et al. (2003) point out that although ecologists are aware of the complex dynamics of the environmental system, they rarely consider the behavioural forces that influence individual decision making. By focussing on scarcity of the provision of ecosystem services, both ecologists and economists will be able to find a common ground that can be the basis for meaningful future research toward the formulation of environmental policy.

While economics is the study of efficient allocation of scarce resources, one of the necessary steps toward achieving the same is to understand the scarcity value of these resources. Unlike a few exhaustible resources like fossil fuel and minerals, many other natural resources are often found to be independent of the market system with their scarcity values not incorporated in the market prices. To incorporate these scarcity values in the valuation, environmental economic approaches have been suggested lately. Though these valuation techniques can do an adequate job of measuring the scarcity of environmental resources in the manner in which they contribute to the production of economic goods, except the efforts by Batabyal et al. (2003), there hardly exists any other worthwhile effort to explicitly measure the value of scarcity rather than the total use value of the resource.

Saleth (2001), while talking of the problems of water pricing, refers to the difference between scarcity value and the total market value (as given by cost) of water. The total cost signals the scarcity value and opportunity cost of water and guides allocation decisions within and across water sub-sectors. Hence, he advocates that the financial function requires water rates to cover the cost of supplying water to users. As in practice, the supply cost is obtained by adding the operation and maintenance costs and the capital costs of constructing the system. However, full cost recovery also requires water rates to reflect the long-term marginal cost (the cost of supplying an additional unit of water including the social cost of externalities). Thus, Saleth (2001) implicitly refers to the scarcity value of the ecosystem services provided by water along with the scarcity value of the economic services. While talking of water pricing policies, Saleth (2001) highlights the role of scarcity value in the following words,

"...The economic and allocative role of water pricing requires water rates to capture the scarcity value (or the marginal productivity/ utility) and to equalize the opportunity costs (the value of water in its next best use) of the resource across uses. As water moves from [the] least productive to [the] most productive uses, places, and time points for efficient allocation, there will be a convergence of the scarcity value, opportunity cost, and long-term marginal cost of the resource. Unfortunately, such a convergence is rarely seen in practice. …Water rates are still subsidized even in countries with a relatively mature water economy such as Australia, Israel, and the United States. This is rooted in the political economy of water as powerful state and user interests often oppose charging the full cost of water. As a result, the gap is vast between the observed water rates and the ideal economic prices of water, as reflected by its scarcity value and opportunity cost".

The notion of "scarcity value" of water emerges more explicitly in a document published by CIE (2004). It clearly states that for water to acquire a "scarcity value", the supply of water must be a limiting constraint to economic activity. In such circumstances, a marginal reduction in access to water will reduce the profitability, wealth, or other measure of economic welfare of the entitlement holder.

Scarcity values have often been referred to as resource rent or scarcity rent. These terms are used to refer to the returns or imputed values of natural resources – that remain after all user costs – have been accounted for. For renewable resources such as water, scarcity rent equates to the above-normal returns to using water in a production process (CIE, 2004). Normal returns are defined as the earnings needed to cover long-term costs, including labour and other variable operating costs (including water charges); overheads, including depreciation and the cost of capital; a 'normal' rate of return on capital that is the minimum rate of return required to hold capital in the activity (sometimes referred to as normal profit); and a margin to cover risk (CIE, 2004). Above-normal returns are defined as the returns in excess of all the costs listed above. They are the surplus above returns that are necessary to retain the use of inputs in the production process. Scarcity rent to the use of water in a particular activity is only available where there is a surplus after all other costs, including water service charges, have been accounted for. The entitlement to take and use water will have value as an asset if these surpluses are expected to be positive, either in their current use or when traded to another (CIE, 2004).

According to Ghosh (2005), the notion of the scarcity value of water should be interpreted as the "unmet demand" for water. Ghosh (2005) has shown how a non-responsive scarcity value to water use in the Cauvery and the Colorado basins has resulted in conflicts over water resources in the basin. Hence, Ghosh and Bandyopadhyay (forthcoming) recommend that in a situation of "non-satiable" water demand, supply augmentation plans can only aggravate the hydropolitical condition in a basin, resulting in enhanced conflicts.

In the previous two sections of this chapter, we have discussed the valuation of economic and ecosystem services of water. It should readily be realised that like total value of water, *scarcity value* of the services can arise from both the economic services of the resources and the ecosystem services of the resources. Due to scarcity of water, losses occur in both economic and ecological services. *Scarcity value* can capture the loss of value in each of these services.

5. From "scarcity" to "scarcity value"

It is clear that the changing water paradigm with its shift away from sole or even primary reliance on finding new sources of supply to deal with perceived new demands, emphasizes incorporation of ecological values into water policy, re-emphasizes the meeting of basic human needs for water services, and consciously breaks off the ties between economic growth and water use (Gleick, 2000). The vision of the need and demand for water as an input in production and social life implies a partial view that fails to consider the implications of the status of water after use (Falkenmark et al., 2004).

A very large proportion of humankind lives downstream of other communities and entire human race stays downstream of precipitation. Indiscriminate upstream activities have often caused problems to the downstream communities, not only because of quantitative loss but also due to losses in qualities. "Reuse of water could be possible in a quantitative sense, but if quality is affected through previous uses, reuse is associated with various costs and hazards" (Falkenmark et al., 2004).

The consideration of the term "scarcity" confines the analysis to the quantitative physical availability of water, without giving much consideration to its qualitative aspects. "Scarcity" mitigation exercises were conducted through supply augmentation plans. This vision dominated the old reductionist vision that existed in the form of what has been called "arithmetical hydrology" (Bandyopadhyay and Perveen, 2004). This is what was being followed in the two basins analyzed in this thesis. This thesis exhibited that the social cost imposed by addressing "scarcity" defined in terms of physical availability of water is a conflict between stakeholders.

Under the new holistic paradigm of "eco-hydrology", the importance of supply augmentation is slowly but steadily getting reduced, and demand management has started taking its place. Notionally, as well as in practice, demand management occurring under scarcity (either through virtual water imports or through other measures), does not mitigate scarcity, but allows for a process of "adaptation" to the scarce conditions. It allows for "playing on the will of nature", rather than "playing against the will of nature". For example, as argued in this thesis, regions under chronic water scarcity, like the Cauvery basin, would be under further stress if it produces high water-consuming crops like rice. Similarly, the Colorado basin produces a high water-consuming fodder crop like alfalfa. These regions should grow low water-consuming crops that are more suited for water availability. By raising less water-consuming crops in the region, scarcity is not mitigated, but scarcity value of the concerned high water-consuming crop is lowered because the unmet or excess demand of water for producing the water-consuming crop goes down.

Israel is the ideal case where one can always explain the attempts to reduce economic "scarcity value" of water, rather than scarcity mitigation. If one looks at scarcity in the region for low physical availability of the resource, one would be horrified to note the state of affairs. Yet, "scarcity value" mitigation through appropriate strategies has totally changed the profile of Israel, thereby calming down the hydropolitical tensions with Jordan and Palestine. Agricultural (virtual water) imports have played a crucial role in this context.

It needs to be understood that "scarcity value" is a holistic measure of not only the state of the resource, but of every type of intervention that can occur on the resource, which rarely gets captured by the notion of "scarcity". The part of the world, where policies are fundamentally based on "arithmetical hydrology", there remains the utmost need to understand the "scarcity value" of the services that water creates. What is intended to be presented in this discussion is that the shift from the old paradigm to the new paradigm should be understood as the shift from dealing with "scarcity" to understanding "scarcity value".

5.1. Development of derivatives markets

One of the important implications for scarcity value framework will be the development of a derivatives market for water resources. This can be thought of in the framework of a futures market for water resources where standardised contracts can be traded. This can have considerable significance for dispute resolution and scarcity mitigation. An efficient futures market for water can help in discovering the price of water. With proper information dissemination, this price will reflect upon the scarcity value of the resource. On the other hand, on the expiry of the contract, rather than physical delivery of the resource (unless a hedge has been rolled over), the settlement can take place at the scarcity value, which will be reflected by the estimated loss due to water scarcity (Ghosh, 2008). This will ensure both liquidity of the contract, and can also help to resolve water-related conflicts.

6. Conclusions

There, however, remains no doubt about the fact that despite the growth of conceptual literature on valuation of ecosystem services, empirical applications have taken place in restrictive numbers. When applications have adopted production-function approaches, the valuations of the ecosystem services have been arrived at by considering a marketed product (in most cases, agricultural). This involves the framing of an agricultural damage function, which is taking place due to effluent emissions (e.g. Kumar et al., 2003; Sekar, 2003). This leaves out an entire range of ecosystem functions that are provided by resource for the sustenance of the planet. Due to the lack of the "optimal" integration of economic sciences and the biological sciences, such an application has not been possible.

At around the same time, the problem with the creation of the best types of models to delineate a framework of the working of interrelationships of the various ecological systems has restricted growth of literature on such applications. The uses of Contingent Valuation Methods, however, are prone to yield hypothetical results because they are based on hypothetical markets. It has also proved highly vulnerable to response biases and individual whims. One must remember that revealed preference methods like Travel Cost and Hedonic Pricing cannot reflect the value of ecosystem services, as market awareness of the ecosystem services has been traditionally low.

On the other hand, all these methods that attempt to evaluate the various functions of water through the utility approach are actually valuing "scarcity", and not the absolute values of water. For non-market methods like contingent valuation methods, the question asked to participants is about their WTP for qualitative or quantitative improvements in the ambient environment. Such a question is being asked to reveal something that does not exist, or to reflect upon the scarcity of the improved quality of the environment. For revealed preference approaches, like travel cost, there is an implicit attempt to put a value on the environment that does not exist in the proximity of the agent. Even for hedonic pricing, somehow it is "scarcity" of the resource that is being valued.

Finally, let us conclude our discussion on valuation by focusing on valuation of Integrated Water Resources Management (IWRM). Valuation of water resources is an important instrument for IWRM As argued in various contexts, valuation can help comprehensive assessment of water development project by keeping the integrity of the full hydrological cycle through a holistic evaluation of economic and ecological systems. On the other hand, it is also argued that that prioritisation of water needs can also be done through valuation. For the new economics of water, valuation provides a new basis of water use and a means to understand and evaluate the emergence of institutions. Hence, to offer the right type of basis for an interdisciplinary knowledge base, it becomes essential to emerge with the right type of valuation methods where one can compare the economic and ecological services of water to offer a benchmark for comparison. Our survey in this paper reveals that such attempts have so far been rare, but are emerging.

REFERENCES

Acharya, G. 1998. Valuing the Environment as an Input: The production function approach. In Acutt, M. and Mason, P. (Eds), *Environmental valuation, economic policy and sustainability: Recent advances in environmental economics.* Cheltenham: Edward Elgar.

Acutt, M. and Mason, P. 1998. An introduction to environmental economics: Theory and application. In Acutt, M. and Mason, P. (Eds), *Environmental valuation, economic policy, and sustainability*. Cheltenham: Edward Elgar.

Alexander, A.; List, J.; Margolis, M. and d'Arge, R. 1998. A method for valuing global ecosystem services. *Ecological Economics* 27(2): 161-170.

Altaf, M. and Hughes, J. 1994. Measuring the demand for improved urban sanitation services: Results of a contingent valuation study in Ouagadougou, Burkina Faso. *Urban Studies* 31(10): 1763-76.

Antle, J. and Capalbo, S. 2002. Agriculture as a managed ecosystem: Policy implications. *Journal of Agricultural and Resource Economics* 27 (1): 1-15.

Arthington, A.H.; Brizga, S.O.; and Kennard, M.J. 1998. *Comparative evaluation of environmental flow assessment techniques: Best practice framework*. LWRRDC Occasional Paper 25/98. Canberra: Land and Water Resources Research and Development Corporation.

Aylward, B.; Bandyopadhyay, J. and Belausteguigotia, J. et al. 2005. Freshwater ecosystem services. In Chopra, K. et al. (Eds), *Ecosystems and Human Wellbeing: Policy Responses* 3: pp. 215–252. New York: Island Press.

Babin, F.; Willis, C. and Allen, P. 1982. Estimation of substitution possibilities between water and other production inputs. *American Journal of Agricultural Economics* 64(1): 148-51.

Balek, J. 1992. *The environment for sale.* New York: Carlton Press.

Bandaragoda, D.J. 1998. *Design and practice of water allocation rules: Lessons from Warabandi in Pakistan's Punjab.* IWMI Research Report 17. Sri Lanka: IWMI (International Water Management Institute).

Bandyopadhyay, J. and Perveen, S. 2004. Interlinking of rivers in India: Assessing the justifications. *Economic and Political Weekly* 39 (50): 5308-16.

Bann, C. 2002. An overview of valuation techniques: Advantages and limitations. *ASEAN Biodiversity* 2(2): 8-16.

Barbier, E.B. and Thompson, J.R. 1998. The value of water: Floodplain versus large-scale irrigation benefits in northern Nigeria. *Ambio* 27(6): 434-40.

Batabyal, A.A.; Kahn, J.R. and O' Neill, R.V. 2003. On the scarcity value of ecosystem services. *Journal of Environmental Economics and Management* 46 (2): 334-52.

Bernardo, D.J.; Whittlesey, N.K.; Saxton, K.E. and Bassett, D.L. 1987. An irrigation model for managing water supplies. *Western Journal of Agricultural Economics* 12(2): 164-73.

Bharadwaj, K. 1974. *Production relations in Indian agriculture*. Cambridge: Cambridge University Press.

Billings, B. and Agthe, D. 1980a. Price elasticities for water: A case of increasing block rates. *Land Economics* 56(1): 73-84.

Billings, B. and Agthe, D. 1980b. Price elasticities for water: A case of increasing block rates: Reply. *Land Economics* 57(2): 276-78.

Billings, B. and Jones, C.V. 1996. *Forecasting urban water demand*. Denver: American Water Works Association.

Billings, R. and Day, W. 1989. Demand management factors in residential water use: The southern Arizona experience. *Journal of American Water Works Association* 87 (3).

Bingham, G.; Bishop, R.; Brody, M.; Bromley, D.; Clark, E.; Cooper, W.; Costanza, R.; Hale, T.; Hayden, G.; Kellert, S.; Norgaard, R.; Norton, B; Payne, J.; Russell, C. and Suter, G. 1995. Issues in ecosystem valuation: Improving information for decision making. *Ecological Economics* 14 (2): 73-90.

Bockstael, N.; Freeman, A.; Kopp, R.; Portney, P. and Smith, V. 2000. On measuring economic values for nature. *Environmental Science and Technology* 34 (8): 1384-1389.

Boland, J. and Whittington, D. 2000. The political economy of water tariff design in developing countries: Increasing block tariffs versus uniform price with rebate. In Dinar, A. (Ed), *The political economy of water pricing reforms*, pp. 215-235. Washington, DC: Oxford University Press.

Bos, M.G. and Walters, W. 1990. Water charges and irrigation efficiencies. *Irrigation and Drainage Systems* 4: 267-78.

Bosworth, B.; Cornish, G.; Perry, C. and Van Steenbergen, F. 2002. *Water charging in irrigated agriculture: Lessons from the literature.* Wallingford: HR Wallingford Ltd.

Bouhia, H. 2001. *Water in the macro economy: Integrating economics and engineering into an analytical model.* Aldershot: Ashgate.

Brown, F.L. 1997. Water markets and traditional water values: Merging commodity and community perspectives. *Water International* 22(1): 2-5.

Buck, S.J.; Gleason, G.W. and Jofuku, M.S. 1993. The institutional imperative: Resolving transboundary water conflict in arid agricultural regions of the United States and the Commonwealth of Independent States. *Natural Resources Journal* 33(3): 595-628.

Bystrom, O. 1998. The nitrogen abatement cost in wetlands. *Ecological Economics* 26(3): 321-331.

Bystrom, O. 2000. The replacement value of wetlands in Sweden. *Environmental and Resource Economics* 16: 347-362.

Chomitz, K.M.; Brenes, E. and Constantino, L. 1998. *Financing environmental services: The Costa Rican experience and its implications.* World Bank: Central America Country Management Unit, Economic Notes Series, No. 10. Washington DC: World Bank.

Chopra, K. and Adhikari, S. K. 2004. Environment development linkages: Modelling a wetland system for ecological and economic value. *Environment and Development Economics* 9(1): 19-45.

Chopra, K.; Rao, C.H.H. and Sengupta, R. (Eds). 2003. *Water resources, sustainable livelihoods, and eco-system services.* New Delhi: Concept Publishing.

Chopra, K.; Leemans, R.; Simons, H. and Kumar, P. 2005. *Ecosystems and human well being, policy responses, findings of the responses working group.* Washington DC: Island Press.

CIE (Centre for International Economics). 2004. *Addressing water scarcity with charges*. Prepared for Queensland Department of Natural Resources and Mines. Canberra & Sydney: Centre for International Economics.

Colby, B.G. 1995. Western US Indian water conflicts: A discussion of economic issues.In Dinar, A. and Loehman, E. T. (Eds), *Water quantity/quality management and conflict resolution: Institutions, processes and economic analyses.* Westport: Praeger.

Colby, B.G. 1998. Negotiated transactions as conflict resolution mechanisms: Water bargaining in the US West. In Easter, W.; Rosegrant, M. and Dinar, A. (Eds), *Markets for water: Potential and performance.* Boston: Kluwer Academic Publishers.

Cosgrove, W. J. and Rijsberman, F. R. 2000. *World water vision: Making water everybody's business.* London: Earthscan.

Costanza, R.; d'Arge., R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P.and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Daily, G.C. (Ed). 1997. *Nature's services: Societal dependence on natural ecosystems.* Washington, DC: Island Press.

Dalton, T.J. and Cobourn, Kelly. 2003. Ecosystem service valuation and watershed resources: An annotated literature review. Preliminary draft prepared for the water challenge program, Theme 2: Multiple uses of upper catchments. CGIAR (Consultative Group of International Agricultural Research).

Dasgupta, P. 2003. Valuation of safe water supplies for urban households. In Chopra, K.; Rao, C.H.H. and Sengupta, R. (Eds), *Water resources, sustainable livelihoods and eco-system services.* New Delhi: Concept Publishing.

De Groot, R.; Wilson, M.A. and Boumans, R.M.J. 2002. A typology for the classification, description, and valuation of ecosystem functions, goods, and services. *Ecological Economics* 41(3): 393-408.

DeRooy, Y. 1974. Price responsiveness of the industrial demand for water. *Water Resources Research* 10(3): 403-6.

Dinar, A. and Subramanian, A. (Eds). 1997. *Water pricing experience: An international perspective.* World Bank Technical Paper 386. Washington, DC: World Bank.

Dinar, A.; Rosegrant, M.W. and Meinzen-Dick, R. 1997. *Water allocation mechanisms: Principles and examples*. World Bank Policy Research Working Paper 1779. Washington, DC: World Bank.

Dupont, D. and Renzetti, S. 2001. Water's role in manufacturing. *Environmental and Resource Economics* 18(4): 411-432.

Dyson, M.; Bergkamp, G. and Scanlon, J. (Eds). 2003. *Flow: The essentials of environmental flows.* Cambridge: IUCN.

Easter, K.W. and Welsch, D.E. 1986a. Implementing irrigation projects: Operational and institutional problems. In Easter, K.W. (Ed), *Irrigation investment, technology, and management strategies for development.* Boulder: Westview Press.

Easter, K.W. and Welsch, D.E. 1986b. Priorities for irrigation planning and investment. In Easter, K.W. (Ed), *Irrigation investment, technology, and management strategies for development.* Boulder: Westview Press.

Easter, K.W. and Tsur, Y. 1995. The design of institutional arrangements for water allocation. In Dinar, A. and Loehman, E.T. (Eds), *Water quantity/quality management and conflict resolution: Institutions, processes and economic analyses.* Westport: Praeger.

Easter, K.W.; Dinar, A. and Rosegrant, M.W. 1999. Formal and informal markets for water: Institutions, performance and constraints. *World Bank Research Observer* 14: 99-116.

Easter, K.W.; Becker, N. and Tsur, Y. 1997. Economic mechanisms for managing water resources: pricing, permits and markets. In Biswas, A.K. (Ed), *Water resources: environmental planning, management and development.* New York: McGraw-Hill.

Ehrlich, P. and Ehrlich, A. 1981. *Extinction: The causes and consequences of the disappearance of species.* New York: Random House.

Farber, S. and Griner, B. 2000. Using conjoint analysis to value ecosystem change. *Environmental Science and Technology* 34(8): 1407-12.

Farber, S.C.; Costanza, R. and Wilson, M.A. 2002. Economic and ecological concepts for valuing ecosystem services. *Ecological Economics* 41(3), 375-392.

Falkenmark, M.; Gottschalk, L.; Lundqvist, J. and Wouters, P. 2004. Towards integrated catchment management: Increasing the dialogue between scientists, policymakers and stakeholders. *Water Resources Development* 20(3): 297-309.

Flessa, K.W. 2004. Ecosystem services and the value of water in the Colorado river delta and estuary, USA and Mexico: Guidelines for mitigation and restoration.In: Proceedings of *International Seminar on Restoration of Damaged Lagoon Environments.* Matsue, Japan. 79-86.

Galindo-Bect., M.S.; Glenn, E.P.; Page, H.M.; Galindo-Bect, L.A.; Hernandez-Ayon, J.M.; Petty, R.L. and Garcia-Hernandez, J. 2000. Analysis of penaeid shrimp catch in the northern Gulf of California in relation to Colorado river discharge. *Fishery Bulletin* 98: 222-225.

Gardner, B.D. and Fullerton, H.H. 1968. Transfer restrictions and misallocations of irrigation water. *American Journal of Agricultural Economics* 50: 556-71.

Garrido, A. 1998. Economic analysis of water markets in the Spanish agricultural sector: Can they provide substantial benefits? In Easter, W.; Rosegrant, M. and Dinar, A. (Eds), *Markets for water: Potential and performance.* Boston: Kluwer Academic Publishers.

Ghosh, N. 2002. Environmental valuation: An instrument for the promotion of a sustainable environment management regime. *Growth* 30(3): 22-29.

Ghosh, N. 2005. *A scarcity value based explanation of transboundary water disputes in water scarce economies.* Doctoral dissertation (unpublished). Indian Institute of Management, Kolkata.

Ghosh, N. and Shylajan, C.S. 2005. Coastal mangrove ecosystems, fishermen's welfare, and anthropogenic externalities: Compensatory payments through mangrove-fishery linkages. In Sengupta, N. and Bandyopadhyay, J. (Eds), *Biodiversity and Quality of Life*, pp. 294-315. New Delhi: Macmillan.

Ghosh, N. and Bandyopadhyay, J. 2002. Valuation of mountain and highland waters: an instrument for the promotion of hydro-solidarity. In: *Proceedings of International Conference on Waters in Mountains.* Megeve: Societe d'Economie Alpestre de la Haute-Savoie.

Ghosh, N. and Bandyopadhyay, J. 2003. Valuation as a tool for the internalisation of ecological-economic factors in upstream-downstream relations. In: *Proceedings of XI World Water Congress.* Madrid: International Water Resources Association.

Ghosh, N. and Bandyopadhyay, J. (forthcoming. A scarcity value based explanation of transboundary water disputes: The case of the Cauvery river basin in India. *Water Policy*.

Ghosh, N. 2008. A new look at integrated water resources management (IWRM) from the perspective of scarcity value of water resources. *Resources, Energy and Development* 5(1): 27-48.

Gibbons, D. 1986. *The economic value of water.* Baltimore: Resources for the Future.

Gittinger, J.P. 1982. *Economic analysis of agricultural projects.* Baltimore: Johns Hopkins University Press.

Giuliano, G. and Spaziani, F. 1985. Water use statistics in industry: Experiences from regional surveys and planning studies in Italy. *Statistical Journal of the United Nations* 3: 229-235.

Gleick, P.H. 2000. The changing water paradigm: A look at twenty-first century water resources development. *Water International* 25(1): 127-38.

Glenn, E.P.; N. Zamora-Arroyo, P.L.;, Briggs, M.; Shaw, W. and Flessa, K.W. 2001. Ecology and conservation biology of the Colorado river delta, Mexico. *Journal of Arid Environments* 49(1): 5-15.

Goldar, B. 2003. Water use in Indian industry: Estimates of value of water and price elasticity of demand. In Chopra, K.; Rao, C.H.H. and Sengupta, R. (Eds), *Water resources, sustainable livelihoods and eco-system services.* New Delhi: Concept Publishing.

Goldar, B.N. and Pandey, R. 2001. Water pricing and abatement of industrial water pollution: Study of distilleries in India. *Environmental Economics and Policy Studies* 4: 95-113.

Gomez-Limon, J. A. and Riesgo, L. 2004. Irrigation water pricing: Differential impacts on irrigated farms. *Agricultural Economics* 31(1), 47-66.

Grebenstein, C. and Field, B. 1979. Substituting for water inputs in US manufacturing. *Water Resources Research* 15(2): 228-32.

Gren, I.M.; Soderqvist, T. and Wulff, F. 1997. Nutrient reductions to the Baltic sea: Ecology, costs and benefits. *Journal of Environmental Management* 51: 123-143.

Griffin, R.C. 1998. The application of water market doctrines in Texas. In Easter, W.; Rosegrant, M. and Dinar, A. (Eds), *Markets for water: Potential and performance.* Boston: Kluwer Academic Publishers.

Guerrero-G.R, H. and Howe, C.W. 2000. Water pricing in Mexico: Principles and reality. Mimeo.

Gulati, A.; Meinzen-Dick, R.S. and Raju, K.V. 2005. *Institutional reforms in Indian irrigation.* New Delhi: Sage.

Halvorsen, R. and Smith, T. 1986. Substitution possibilities for unpriced natural resources: Restricted cost functions for the Canadian mining industry. *Review of Economics and Statistics* 68(3): 398-405.

Hanley, N. 1998. Economic incentives for the control of pollution: Modelling tradable permit systems. In Acutt, M. and Mason, P. (Eds), *Environmental valuation, economic policy and sustainability.* Cheltenham: Edward Elgar.

Hannon, B. 2001. Ecological pricing and economic efficiency. *Ecological Economics* 36(1): 19-30.

Harris, J. and Tate, D. 2002. *Economic principles and concepts as applied to municipal water utilities: Final report.* Kanata: GeoEconomics Associates Incorporated.

Hartman, L.M. and Seastone, D. 1970. *Water transfers: Economic efficiency and alternative institutions.* Baltimore: Johns Hopkins Press.

Hawkins, K. 2003. *Economic valuation of ecosystem services.* Mimeo.

Hazell, P.B.R. and Norton, R.D. 1986. *Mathematical programming for economic analysis in agriculture.* New York: Macmillan.

Hearne, R.R. and Easter, K.W. 1995. *Water allocation and water markets: An analysis of gains-from-trade in Chile.* World Bank Technical Paper 315. Washington, DC: World Bank.

Holdren, J. and Ehrlich, P. 1974. Human population and the global environment. *American Scientist* 62: 282-292.

Holland, S.P. and Moore, M.R. 2003. Cadillac desert revisited: Property rights, public policy, and water-resource depletion. *Journal of Environmental Economics and Management* 46(1): 131-55.

Howarth, R.B. and Farber, S. (2002). Accounting for the value of ecosystem services. *Ecological Economics* 41(3): 421-429.

Howitt, R.E. 1998. Spot prices, option prices and water markets: An analysis of emerging markets in California. In Easter, W.; Rosegrant, M. and Dinar, A. (Eds), *Markets for water: Potential and performance.* Boston: Kluwer Academic Publishers.

Howitt, R.E. and Vaux, H. 1995. Competing demands for California's scarce water. In Dinar, A. and Loehman, E.T. (Eds.), *Water quantity/quality management and conflict resolution: Institutions, processes and economic analyses.* Westport: Praeger.

Johansson, R.C. 2000. *Pricing irrigation water: A literature survey.* World Bank Policy Research Working Paper 2449. Washington DC: World Bank.

Johansson, R.C.; Tsur, Y.; Roe, T.L.; Doukkali, R. and Dinar, A. 2002. Pricing irrigation water: A review of theory and practice. *Water Policy* 4(2): 173-99.

Jordan, J.L. and Elnagheeb, A.H. 1993. Willingness to pay for improvements in drinking water quality. *Water Resources Research* 29(2): 237-245.

Kaiser, B. and Roumasset, J. 2002. Valuing indirect ecosystem services: The case of tropical watersheds. *Environment and Development Economics* 7: 701-714.

Kaplowitz, M. 2000. Identifying ecosystem services using multiple methods: Lessons from the mangrove wetlands of Yucatan, Mexico. *Agriculture and Human Values* 17: 169-179.

Kerr, J. 2002. Watershed development, environmental services, and poverty alleviation in India. *World Development* 30(8): 1387-1400.

Klauer, B. 2000. Ecosystem prices: Activity analysis applied to ecosystems. *Ecological Economics* 33 (3): 473-486.

Kumar, P.; Love, A.; Sharma, R.S. and Babu, C.R. 2003. Valuing the hydrological impact of changing land-use: A case of Yamuna floodplain wetland ecosystems, Delhi. In Chopra, K.; Rao, C.H.H. and Sengupta R. (Eds), *Water resources, sustainable livelihoods and eco-system services.* New Delhi: Concept Publishing.

Kumar, S. 2006. Analyzing industrial water demand in India: An input distance function approach. *Water Policy* 8(1): 15-29.

Lazo, J.K. 2002. Economic valuation of ecosystem services: discussion and application. *Drug Chem Toxicol* 25 (4): 349-74.

Lemly, A.D.; Kingsford, R.T. and Thompson, J.R. 2000. Irrigated agriculture and wildlife conservation: Conflict on a global scale. *Environment Management* 25(5): 485-512.

Lindgren, A. 1999. The value of water: A study of the stampriet aquifer in Namibia. Masters Thesis, UMEA University.

Mahendrarajah, S. 1999. Small-scale water resource systems and environment: Models for management. In Mahendrarajah, S.; Jakeman, A.J. and McAleer, M. (Eds), *Modelling change in integrated economic and environmental systems.* Chichester: John Wiley.

Marino, M. and Kemper K.E. 1999. *Institutional frameworks in successful water markets.* World Bank Technical Paper 427. Washington DC: World Bank.

Mascollel, A.; Whinston, M.D. and Green, J.R. 1995. *Microeconomic theory.* New York: Oxford University Press.

Meinzen-Dick, R. 1997. Farmer participation in irrigation: 20 years of experience and lessons for the future. *Irrigation and Drainage Systems* 11: 103-118.

Mitsch, W.J., and Gosselink J.G. 2000. *Wetlands.* 3rd. Ed. New York: John Wiley.

Molden, D. and Fraiture, C. 2004. Investing in water for food, ecosystems and livelihoods. Discussion draft at Comprehensive assessment of water management in agriculture. Stockholm.

Mollinga, P. P. 2003. *On the Waterfront.* Hyderabad: Orient Longman.

Mooney, H.A. and Ehrlich, P.R. 1997. Ecosystem services: A fragmentary history.In Daily, G.C. (Ed), *Nature's services: Societal dependence on natural ecosystems*. pp. 11-19. Washington,DC: Island Press.

MoWR Ministry of Water Resources). 2002. *National Water Policy*. New Delhi: Ministry of Water Resources, Government of India..

Musser, N. Wesley; Musser, Lynn M.; Laughland, A.S. and Shortle J.S. 1995. Contingent valuation in resolving local public water problems. In Dinar, A. and Loehman, E. T. (Eds), *Water quantity/quality management and conflict resolution: Institutions, processes and economic analyses.* Westport: Praeger.

Nagaraj, N.; Shankar K. and Chandrakanth, M. G. 2003. Pricing of irrigation water in Cauvery basin. *Economic and Political Weekly* 38 (43), 4518-20.

Naiman, R.J.; Bunn, S.E.; Nilsson, C.; Petts, G.E.; Pinay, G. and Thompson, L.C. 2002. Legitimizing fluvial ecosystems as users of water. *Environmental Management* 30: 455-467.

OECD. 1995. *The economic appraisal of environmental projects and policies: A practical guide.* Paris: OECD.

OECD. 2002. *Handbook of biodiversity valuation: A guide for policymakers.* Paris: OECD.

Omezzine, A., M.; Zaibet, Chebaane and Zaibet, L. 1998. Analysis of agricultural water allocation and returns in the Sultanate of Oman. *Water International* 23 (4): 249-56.

Pan, W.; Tang, T.; Deng, H. and Cai, Q. 2002. Lake ecosystem services and their ecological valuation – a case study of Baoan Lake in Hubei province. *Ying Yong Sheng Tai Xue Bao* 13(10): 1315-8.

Postel, S.L.; Daily, G.C. and Ehrlich, P.R. 1996. Human appropriation of renewable fresh water. *Science* 271:785-788.

Ragan, G.E.; Makala, C.J. and Young, R.A. 1993. *Improved estimates of economic damages from residential use of mineralized waters*. Fort Collins, Colorado: Colorado Water Resources Research Institute.

Rao, K. L. 1975. *India's water wealth.* New Delhi: Orient Longman.

Rao, P.K. 1988. Planning and financing water resource development in the United States: A review and policy perspective. *American Journal of Economics and Sociology* 47(1): 81-96.

Rees, J. 1969. *Industrial demand of water: A study of South East England.* London: Weidenfeld and Nicolson.

Renzetti, S. 1988. An econometric study of industrial water demands in British Columbia, Canada. *Water Resources Research* 24(10): 1569-75.

Renzetti, S. 1992. Estimating the structure of industrial water demands: The case of Canadian manufacturing. *Land Economics* 68(4): 396-404.

Renzetti, S. 2001.The state of raw water and water utility operations. In Moody, D. and Wouters, P. (Eds). *Globalisation and Water Resources: The Changing Value of Water.* Proceedings of the American Water Resources Association/University of Dundee International Conference. Dundee, Scotland. 6-8 August 2001.

Renzetti, S. and Dupont, D. 2003.The value of water in manufacturing. *CSERGE Working Paper* ECM 03-03.

Revenga, C.; Brunner, J.; Henninger, N.; Kassem, K. and Payne, R. 2000. *Pilot analysis of freshwater ecosystems: Freshwater systems*. Washington, DC: World Resources Institute.

Reynaud, A. 2003. An econometric estimation of industrial water demand in France. *Environmental and Resource Economics* 25(2): 213-232.

Rhodes, G.F. and Sampath R.K. 1988. Efficiency, equity and cost recovery. Implication of water pricing and allocation schemes in developing countries. *Canadian Journal of Agricultural Economics* 36:103-117.

Richter, B.D.; Baumgartner, J.V.; Wigington, R. and Braun D.P. 1997. How much water does a river need? *Freshwater Biology* 37: 231-249.

Rijsberman, F.R. and Molden, D. 2001. Balancing water uses: Water for food and water for nature. In: Thematic Background Paper, *International Conference on Freshwater*, pp. 43-56. Bonn, Germany, 3-7 December 2001

Rogers, P. 1993. The value of cooperation in resolving international river basin disputes. *Natural Resources Forum* 17(2): 117-31.

Rosegrant, M. and Binswanger H. 1994. Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation. *World Development*, 22(11): 1613-1625.

Rudra, A. 1982. *Indian agricultural economics: Myths and realities.* New Delhi: Allied Publishers.

Saleth, M. 1997. "India" in Dinar, A. and Subramanian, A. (Eds), *Water pricing experience: An international perspective.* World Bank Technical Paper 386. Washington, DC: World Bank.

Saleth, M. R. 2001. Water pricing: Potential and problems. In Meinzen-Dick, R. S. and Rosegrant M.W. (Eds), *Overcoming water scarcity and quality constraints*. IFPRI (International Food Policy Research Institute).

Sampath, R.K. 1990. Measures of inequity for distribution analysis of large public surface irrigation systems: A welfare theoretic approach. In Sampath, R. and Young, R. (Ed). *Social, economic, and institutional issues in Third World irrigation management.* Boulder: Westview Press.

Sampath, R.K. 1992 Issues in irrigation pricing in developing countries. *World Development* 20: 967-77.

Sangal, S.P. 1991. Pricing of irrigation water in India. *Economic and Political Weekly* 24(46): 2645-51.

Sankar, U. 1999. Econometric applications in agricultural economics. In Krishna, K.L. (Ed), *Econometric applications in India.* New Delhi: Oxford University Press.

Scott, M.J.; Bilyard, G.R.; Link, S.O.; Ulibarri, C.A. and Westerdahl, H.E. 1998. Valuation of ecological resources and functions. *Environmental Management* 22 (1): 49-68.

Seagraves, J.A. and Easter, K.W. 1983. Pricing irrigation water in developing countries. *Water Resources Bulletin* 4: 663-71.

Seckler, D.; Sampath, R.K. and Raheja, S.K. 1988. An index for measuring the performance of irrigation management systems with an application. *Water Resources Bulletin* 24: 855-60.

Seckler, D.; Amarasinghe, U.A.; Molden, D.; De Silva, R. and Barker, R. 1998. *World water demand and supply, 1990 to 2025: Scenarios and issues.* Research Report 19. Colombo: International Water Management Institute.

Sekar, C. 2003. Industrial pollution and its impacts on soil, water, crop, livelihood status and ecology: A micro-level investigation in Vellore district in Tamil Nadu. In Chopra, K.; Rao, C.H.H. and Sengupta, R. (Eds), *Water resources, sustainable livelihoods, and eco-system services.* New Delhi: Concept Publishing.

Sen, A.K. 1973. *On economic inequality.* Oxford: Clarendon Press.

Simpson, D.R. 2001. A note on the valuation of ecosystem services in production. *Discussion Paper, pp.* 01-16. Resources for the Future. Wasington DC.

Small, L.E. and Carruthers, I. 1991. *Farmer financed irrigation: The economics of reform.* Cambridge: Cambridge University Press.

Smith, R.B.W. and Tsur, Y. 1997. Asymmetric information and the pricing of natural resources. *Land Economics* 73(3): 392-403.

Somanathan, E. and Ravindranath, R. 2006. Measuring the marginal value of water and elasticity of demand for water in agriculture. *Economic and Political Weekly* 41(26): 2713-15.

Southgate, D. 2000. Estimating irrigation benefits: A methodological overview. *Contributing paper at the World Commission on Dams.* Prepared for Thematic Review III.1: Economic, financial and distributional analysis.

Stewart, W. C. 1996. Economic assessment of the ecosystem. *Sierra Nevada Ecosystem Project: Final report to Congress, vol. III, Assessments and scientific basis for management options.* Davis: University of California, Centers for Water and Wildland Resources.

Thobani, M. 1997. Formal water markets: Why, when and how to introduce tradable water rights? *World Bank Research Observer* 12(2): 161-79.

Tsur, Y. and Dinar A. 1995. *Efficiency and equity considerations in pricing and allocating irrigation water.* World Bank Policy Research Working Paper 1460. Washington DC: World Bank.

Tsur, Y. and Dinar, A. 1997. On the relative efficiency of alternative methods for pricing irrigation water and their implementation. *World Bank Economic Review* 11(2): 243-62.

Tsur, Y.; Roe, T.; Doukkali, R. and Dinar, A. 2004. *Pricing irrigation water: Principles and cases from developing countries.* Washington: Resources for the Future.

Turnoskvsky, S. 1969. The demand for water: Some empirical evidence on consumers' response to a commodity uncertain in supply. *Water Resources Research* 5(2): 350-61.

Vaidyanathan, A. 1994. Report on pricing of irrigation water. *Indian Journal of Agricultural Economics* 49 (1): 107-23.

Vaidyanathan, A. 1999. *Water resource management: Institutions and irrigation development in India.* New Delhi: Oxford University Press.

Vaidyanathan, A. 2004. Political economy of water pricing: Some lessons from India.l In Dorin, B. and Jullien, T. (Eds) *Agricultural incentives in India: Past trends and prospective paths towards sustainable development*. New Delhi: Manohar.

Vaidyanathan, A. 2006. *India's water resources: Contemporary issues in irrigation.* New Delhi: Oxford University Press.

Wang, H. and Lall, S. 1999. *Valuing water for Chinese industries: A marginal productivity assessment.* World Bank Policy Research Working Paper 2236, Washington, DC: World Bank.

Whitaker, M.D. and Alzamora, J. 1990. Irrigation and agricultural development. In Whitaker, M.D. and Colyer, D. (Eds), *Agriculture and economic survival: The role of agriculture in Ecuador's development*. Boulder, Colorado: Westview Press.

Whittington, D.; Lauria, D. T.; Wright, A.M.; Choe, K.; Hughes, J. A. and Swarna, V. 1993. Household demand for improved sanitation service in Kumasi, Ghana: A contingent valuation study. *Water Resources Research* 29(6): 1539-1560.

Whittington, D.; Lauria, D.T. and Mu, X. 1991. A study of water vending and willingness to pay for water in Onitsha, Nigeria. *World Development* 19: 179-198.

Whittington, D.; Briscoe, J.; Mu, X. and Barron, W. 1990. Estimating the willingness-to-pay for water services in developing countries: A case study of the use of contingent valuation surveys in southern Haiti. *Economic Development and Cultural Change* 38: 293-311.

Wilson, M., and Howarth, R. 2002. Discourse-based valuation of ecosystem services: Establishing fair outcomes through group deliberation. *Ecological Economics* 41(3): 431-443.

Yaron, D. 1997."Israel" in Dinar, A. and Subramanian, A. (Eds), *Water pricing experience: An international perspective.* World Bank Technical Paper 386. Washington, DC: World Bank.

Young, R.A. 1973. Price elasticity of demand for municipal water: Tucson, AZ. *Water Resources Research* 9(4): 1068-072.

Young, R.A. 1996. *Measuring economic benefits for water investments and policies.* World Bank Technical Paper 338. Washington, DC: World Bank.