Water Policy 8 (2006) 1–13

Water in the economy of Tamil Nadu, India: more flexible water allocation policies offer a possible way out of water-induced economic stagnation and will be good for the environment and the poor

Ramesh Bhatia[b], John Briscoe[a], R. P. S. Malik[a,c], Lindy Miller[d], Smita Misra[a], K. Palainisami[e] and N. Harshadeep[f]

[a]*The World Bank, 70, Lodhi Estate, New Delhi, India*

[b]*Corresponding author. Resources and Environment Group, SU-125 Vishakha Enclave, New Delhi, India. Tel: 650 638 1560, Fax: 650 506 1236. E-mail:rameshbhatia77@yahoo.com*

[c]*Agricultural Economics Research Centre, University of Delhi, Delhi, India*

[d]*Harvard University, USA*

[e]*Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, India*

[f]*The World Bank, Washington, D.C.*

Received 8 July 2005; accepted in revised form 4 October 2005

Abstract

The state of Tamil Nadu, India, is in the grips of a water crisis, with demand far outstripping supply. As the economy of the state grows, this crisis is going to become ever more serious. To date the focus of state water policy has been on trying to augment supplies, from within the state (even from desalinization) and from neighboring states. In addition, the water use is regulated in a way that does not encourage the highest value uses. International experience shows that supply-side measures must be complemented by demand-side measures and that practice must move away from fixed, command-and-control allocation policies towards flexible allocation mechanisms, which facilitate the voluntary movement of water from low to high-value uses.

This study addresses the question of whether such a change in allocation policies is worth doing. It addresses this question by developing optimization models for each of the 17 river basins in Tamil Nadu (including an assessment of the economic value of water in different end-uses – agriculture, domestic and industry), then using an input–output model embedded in a social accounting matrix (SAM), to assess the impact of these changes on the state economy and on different rural and urban employment groups.

The results suggest that a shift to a flexible water allocation system would bring major environmental, economic and social benefits to the state. Compared with the current "fixed sectoral allocation" policy, a flexible allocation policy would, in 2020, result in 15% less overall water used; 24% less water pumped from

doi: 10.2166/wp.2005.049

aquifers; 20% higher state income; with all strata, rich and poor, benefiting similarly, with one important exception, that of agricultural laborers.

Keywords: Economic value of water; Optimization models; Social Accounting Matrix (SAM); Tamil Nadu; Water allocation policies

---

Overview of the situation

Tamil Nadu has a population of 60 million people, of which 55% are urbanized. The state is in the grips of a water crisis. Even though the total water potential of the state is about 46540 million m^3 (MCM), water availability per capita is less than 500 m^3 per capita per year, well below the 1000 m^3 figure generally considered to signal "water scarcity". In many ways, the state is well on the road to a situation that other states in India could face in the coming years. Newspaper accounts over the past few years are replete with descriptions of:

- Severe water scarcity and droughts in the lower Cauvery Delta
- Disputes between Tamil Nadu and the neighboring states of Karnataka and Andhra Pradesh and Kerala over the allocation of inter-state water
- Major problems in obtaining an adequate raw water supply for Chennai City
- Dramatic reductions in groundwater tables
- Reduction in the storage capacity of the tank system to the tune of 30%
- Growing conflicts between different water using groups in the state
- Pollution threats to scarce water supplies.

The state has responded to these crises in several ways.

The first approach is to attempt to capture a larger proportion of rainfall, by creating large and small dams and rainwater harvesting structures. As such Tamil Nadu has 79 reservoirs of which 27 are large. Of the 19335 micro watersheds (each 500 hectares) identified, about 4000 have so far been developed through different programs. The impact of such efforts has been limited, since the yield/storage ratio declines substantially at higher storage levels and because Tamil Nadu already has substantial storage (in dams alone enough to hold about 230 days of rainfall, much higher than the all-Indian of about 60 days). As is apparent to users in the lower Vaigai and other basins, the main impact of upstream water harvesting structures (large and small) is often simply to rob the downstream "Peters" to create new implicit water entitlements for the upstream "Pauls". The appropriate mental model in water-stressed Tamil Nadu is one of a zero-sum game, in which increased allocations of water to one user (often well-identified and grateful for a politician's benevolence) necessarily mean a corresponding decrease in allocations to other users (often dispersed and less identifiable).

The second approach is for the state to try to bring more water into the state. There have thus been major efforts to hold on to water that Tamil Nadu has historically obtained from neighboring states (such as from the 100 year-old inter-basin transfer from Kerala via the Periyar project) and to try and get more water from both inter-state rivers such as Cauvery in which Tamil Nadu is a lower riparian state (as in the case of the Cauvery) or from other peninsular rivers (such as the Krishna through the Telugu Ganga project, or eventually from the Godavari from an "inter-linking project"). A review of these inter-state issues is beyond the scope of this analysis; here it is simply germane to note that Tamil Nadu has, in fact, obtained very little water from very great efforts of this sort.

The third approach is to augment supplies for cities and industry by desalination and treating and re-use of wastewater. There are few successful cases where such investments have worked (including the reverse osmosis plants run by several major industries in Chennai) and other cases – especially industrial – where such investments would make good sense. However, outside industrial uses, the cost per unit of water thus produced is orders of magnitude greater than the revenues yielded and it is thus unlikely that such schemes will play a major role in the short term, at least.

The fourth approach is to rehabilitate and modernize tanks through external and internal funding. However of the 39200 tanks in the state, 90% are Panchayat Union tanks with a command area of 40 hectares and less. These demand active local community participation for rehabilitation and management, which is a difficult component to implement.

These primarily supply side augmentation, large and small, from sources within and beyond the state and have, in recent years, been complemented by coping mechanisms on the demand side. Recent repeated droughts have forced the state to advise farmers to adopt less water intensive cropping patterns and irrigation systems. Tamil Nadu has set national precedents in mandating rainwater harvesting in cities and towns to recharge groundwater.

In summary then, the response of the state has primarily been one of attempts at supply-side augmentation, large and small, from sources within and beyond the state coupled with some demand side management interventions. In this context, the situation in the capital city of Chennai is revealing and a harbinger of things to come.

For years Chennai has faced severe water shortages. The whole battery of supply augmentation options has been discussed and several (reverse osmosis of wastewater, some out-of-state inter-basin transfers from Andhra Pradesh and now an intra-state inter-basin transfer from the Veeranum Tank in the Cauvery Basin) have been partially and sometimes intermittently implemented. In light of the desperate situation in Chennai, the water supply authority (Metrowater) has also explored a unique and quite different approach. Noting that farmers in the neighboring AK aquifer have been using large quantities of water for growing paddy while Chennai has been without water, it is obvious that overall welfare would be higher if that water were transferred from agriculture to the city (Briscoe, 1997). Although the official "hierarchy of water priorities" in Tamil Nadu's Water Policy (as in the National one) is that "water for human use has highest priority", in fact it is (and should be) impossible simply to confiscate the water from the AK farmers "for the greater good". Accordingly, Metrowater devised an approach whereby "forbearance payments" were made to willing farmers who agreed to forego their customary use of water and to allow the city to use that water. Imperfect as this experiment has been[1] it is a breakthrough in a number of ways – it arose because supply-side solutions were insufficient and it

[1] The original concept was that water users in the aquifer would be assigned formal water entitlements, that the sum of the entitlements would, over time, be adjusted so that abstractions balanced recharge and that the city would buy water from farmers who received "forbearance payments". The city's desperation has meant that water has, in fact, been purchased from farmers, but that this has been done without the necessary hydrological safeguards being in place and without serious attention being given to institutionalization of the transfer system. Metrowater has, however, initiated hydrological and institutional and legal studies so that this rather haphazard – but interesting – arrangement evolves into a sound flexible water management system.

abandoned the traditional command-and-control system in favor or a flexible "willing seller/willing buyer" approach in which there was voluntary, consensual movement of water from low to high value uses. The experiment, despite largely flexible resource regulation lacunae, has proved generally successful with farmers queuing up to sell water for assured revenues (most still growing crops) and Metrowater being able to buy water at a fraction of what it would cost to develop alternative sources.

The AK experiment mirrors the evolution of water management in recent decades in many arid areas of the world. The experience of countries which have faced such "zero-sum" situations shows that there needs to be (a) less attention given to supply augmentation possibilities and (b) much more attention to policies which will get "more for less" and which will mitigate the economic, social and environmental impacts of declining per capita supplies. This kind of reallocation would be inevitable over time given that the non-irrigation uses are often small and are often higher value (e.g. drinking, industrial).

This paper looks at one of the more important of such policies, namely a switch from largely command-and-control water allocation policies to more flexible allocation policies, which facilitate the partial reallocation of scarce water supplies from lower to higher value uses. Experience in other arid parts of the world shows that such changes can be effected, but that they require political will and far reaching changes in law and institutions. The question thus arises – is it worth the Government of Tamil Nadu considering moving from the known command-and-control water allocation methods to a radically different "flexible allocation" regime? This study is designed to answer this question, by assessing the economic, environmental and social impact of a switch from command-and-control allocation methods to flexible allocation procedures.

Methods

The method followed in this study was as follows:

Step One: The economic value of water in different end uses (industrial, agricultural and domestic uses) was determined using standard economic methods and using data collected in field studies in Tamil Nadu as well as from published reports.

Step Two: An optimization model was developed for each of the aggregated seventeen river basins in Tamil Nadu and calibrated with the hydrological and water use data for that basin. The existing reservoir, tank and well irrigation system and crop season were incorporated in the model accordingly. Allocations of water for environmental purposes are set exogenously. For each basin the model was then run to compare the water allocations which would emerge from (a) policies which fix the proportion of water going to each end use and (b) flexible allocation policies in which water moves to the use where the economic value of water is highest. The optimization models, then, give an estimate of the direct economic impact (levels of production of different types of goods and services) of different water allocation regimes and an indication of the environmental impact (as reflected in the abstractions of water from surface and groundwater sources).

Step Three: The intriguing (and challenging) fact is that changes in water allocation not only have direct effects (on the production of paddy and textiles, for example) but these direct effects "ripple backwards" (to suppliers of agricultural inputs, for example), "ripple forwards" (to industries who use agricultural products, for example) and "outwards" (by the changes in incomes and consumption of individuals who are affected in the process). The third step in the analysis accordingly involves the construction and calibration of an input–output matrix of the economy of Tamil Nadu and using the input–output model (embedded in a SAM-based fixed price multiplier model) to simulate the sum of the direct and indirect impact of the changed water management practices on the economy of the state.

Step Four: An important concern in policy making is not only the aggregate economic impact of a policy change, but the way in which such an aggregate impact affects different social strata and particularly the poor. This is of particular importance because similar analyses of infrastructural and agricultural interventions in India (Bhatia & Malik, 2004; Hazell & Ramasamy, 1991) have shown that the indirect effects are as large as the direct effects and that while the owners of assets are the major "direct" beneficiaries, growth leads to increases in the incidence and remuneration of labor and thus the owners of labor (including the poor) are the major beneficiaries of the indirect impact of growth-inducing policy changes.

Determining economic value of water in different uses

The value of water in alternative uses has been estimated as follows:

- Agriculture: The value of water in agriculture has been defined as the returns to water and family labor (including management) per hectare for different crops. The value of water in agriculture thus differs not only from crop to crop within the same basin but also across crops in different basins.
- Industry: The economic value of water for the industry is estimated by determining the willingness to pay (WTP) by the industry, ascertained on the basis of interviews with some industrialists in the Coimbatore region, as well as on the basis of the cost of next expensive alternative source of water supply for the industry.
- Domestic sector: The value of water for the domestic sector is the WTP for water by the rural and urban households. The WTP is based on household choices with respect to household connection (differentiated by the service level), yard connection or shared connections in each basin.

Optimization model for reallocation of water between competing uses: an overview

To assess the direct impact of water allocation between different water users and to assess the economic value of additional water, basin-specific optimization models were developed. For each of the 17 basins[2] a single-period linear programming model is developed which (a) takes into account exogenously-set water allocations for ecological, environmental and in-stream uses (which are varied in different scenarios) and (b) determines the economically optimal allocation of water amongst alternative water using sectors (agriculture, industry and domestic) and amongst alternative choice variables (different crops, levels of service and industries) within the individual water using sectors.

[2] The model does not consider the possibility of inter-basin transfer of water (except in specified cases) since inclusion of such an option would require making assumptions about the availability of institutions and the physical infrastructure needed to undertake these transfers. Though such a transfer is possible in the long run for the present exercise this option has not been included.

Mapping direct and indirect impact of water management on the Tamil Nadu economy

The direct and indirect impact of different water management practices on the Tamil Nadu economy have been mapped in the framework of an input–output model[3] of the Tamil Nadu economy. The input–output model has been supplemented by the development of a social accounting matrix (SAM), which makes it possible to track these changes in particular social groups. The input–output model, when combined with a SAM, means that the full economic effects of any policy (in this case more flexible water allocation) can be traced through the economy and that the impact of these changes on different sections of society in the population can be assessed.

A schematic representation of the way in which the optimization and input–output/SAM-based fixed price multiplier models are linked is presented in Fig. 1. The SAM interactions and the circular flow of income are presented schematically in Fig. 2.

The water allocation scenarios considered

The following alternative scenarios have been formulated for assessing the implications of adoption of more flexible water allocation policies on the Tamil Nadu economy:

- Fixed water allocation: This assumes continuation of current priorities in water allocation to the year 2020. The future allocation and use is based on maintaining the shares of water in agriculture, domestic, industry at the ratios prevailing in the base year of 2000. Additional supplies of sustainable groundwater are allocated amongst the different water using sectors in the same proportion as in 2000. (This scenario could be described as "equal sharing of the pain of water shortages" across the water-using sectors.)
- Flexible water allocation: This scenario is based on reallocation of available water between agriculture, domestic and industry based on the economic value of water in these sectors. The overall volume of water available in the base-case scenario remains the same as in 2000 but water is allocated (by the optimization model) to all sectors based on the estimated economic value of water in each sector (as defined by the willingness to pay (WTP) for water in each sector). It is assumed that control structures for water redistribution amongst various users are in place and incentives to transfer water from one use to another will be present. However, owing to considerations of livelihood and food security at the local level, basin-wise lower bounds have been put in place for the area used for food crops at a level equivalent to 50% of the area under these crops in the year 2000. Similarly, for industry, lower bounds for output have been placed at the 2000 level at the basin level. Both agricultural and industrial outputs are constrained, through upper bounds, at a level equivalent to their exogenously projected output level in 2020 at the state level.

[3] The input–output table of Tamil Nadu is not available. We have attempted to build an input–output table of the state by extrapolating the input–output coefficients from the national level table. We do realize the shortcomings of adopting this approximation, however owing to the quality of the existing data base and the absence of previous studies on the subject, we had no other option but to follow this approach. We hope future studies will build upon this work with more detailed studies that should help refine the analysis carried out in this study. We do however feel that the essence of the results presented here is unlikely to undergo any significant change.

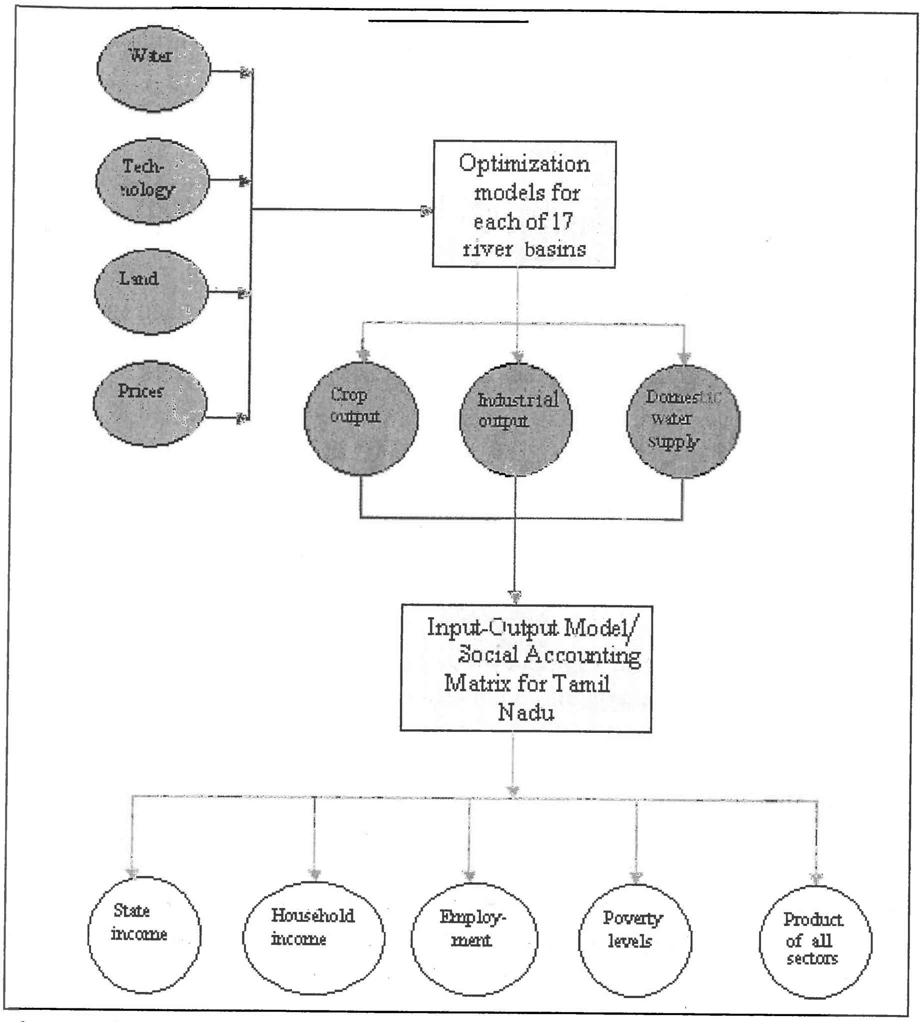

Fig. 1. Linkages between the optimization and input–output/SAM models.

Findings

Changes in water use patterns and some environmental impacts

As shown in Fig. 3, the two management options (flexible allocation and fixed allocation)led to quite different patterns of water use in the economy of Tamil Nadu in 2020. Specifically:

- Agricultural water use would be 32% less (20.0 BCM per year rather than 29.4 BCM per year).
- The dominance of agricultural water use would decline substantially (from 87% under the fixed approach to 70% under the flexible approach).
- The water constraints under which industry operates would be substantially relieved, with industrial use accounting for 4.3 BCM per year under the flexible scenario versus 1.3 BCM per year under the fixed scenario.

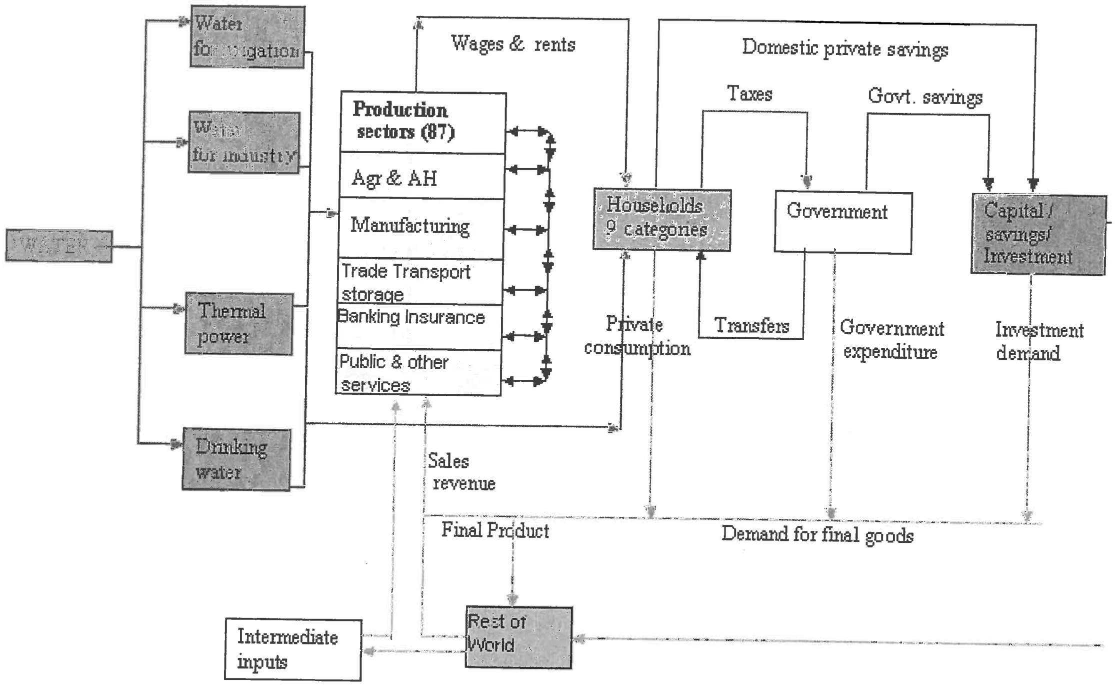

Fig. 2. SAM interactions and circular flows of income.

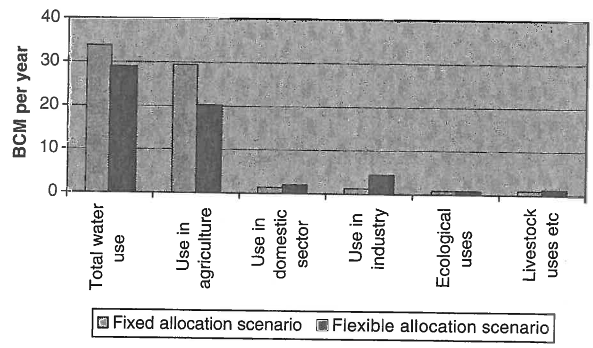

Fig. 3. Total and sectoral water use in 2020 under two management scenarios.

- Similarly, domestic users would benefit substantially, with their use rising from 1.4 BCM per year under the fixed allocation scenario to 2.9 BCM per year under the flexible scenario.

While the focus of this study is on the economic implications of different patterns of water use, the analysis does throw some light onto the likely environmental impact of the different approaches to water management. Adoption of the flexible rather than fixed allocation approach would substantially reduce the pressure on the water resource base and, accordingly, have a substantial positive impact on the environment. Specifically, there would be:

- a 15% reduction in total water use (from 33.8 BCM per year to 29.2 BCM per year) and
- 24% less water pumped from aquifers (15.0 BCM per year rather than 19.8 BCM per year).

Overall economic impact

The SAM-based fixed-price multiplier model (with embedded input–output model) takes the results of the optimization models for 17 basins as inputs and then determines the aggregate (direct plus indirect) impacts of different scenarios. The results (Table 1) show that were the government of Tamil Nadu to adopt flexible water allocation policies, the state income (as measured by gross value added, GVA) in 2020 would be 21% greater than if allocations to sectors were to remain fixed. The composition of GVA would, however, be markedly different. Agriculture's share of GVA would fall from 1.8% (in the "fixed allocation scenario") to 1.1% (in the flexible scenario), whereas the contribution of industry would rise (6% under "fixed"; 11% under "flexible"). The contribution of the tertiary sector would fall in relative terms, but increase by 11% in absolute terms.

Direct and indirect impacts – the multiplier

These changes in value added occur because of (i) changes in the GVA of sectors (agriculture and industry, including electricity and gas) directly affected by the availability of water, (ii) changes in GVA in sectors which are indirectly impacted by changes in the directly impacted sectors and (iii) changes in consumption-induced impacts. The magnitude of indirect impact via the inter-industry linkage and consumption-induced impact depend on the strength of linkages between various sectors within the given economy (as captured in the structure of the input–output model). Multiplier analysis provides an approach for comparing the "indirect effects" (inter-industry linkages and consumption-induced effects) with the direct impact of the policy changes. The multiplier value is estimated to be 1.94, which means that for every 100 Rupee of value-added generated directly as a result of the adoption of more flexible water policies, another 94 Rupees are generated in the form of indirect or ripple effects. Thus the indirect economic impact of adopting more flexible inter-sectoral water allocation policies is roughly as large as the direct impact (a multiplier that that is similar to that from a number of other water studies (Bhatia & Malik, 2004; Hazell & Ramasamy, 1991; Bell *et al.*, 1982; Ortolano & Kusing, 2002)).

Table 1. Comparison of gross value added in 2020 by major sectors under the two scenarios.

	Water allocation scenarios				
	Fixed		Flexible		
Sector	GVA (billion Rs)	Total GVA (%)	GVA (billion Rs)	Total GVA (%)	Percent change in GVA
Agriculture	107	1.8	76	1.1	−29
Industry	360	6.0	773	10.7	+115
Electricity and gas	51	0.9	322	4.5	+537
Tertiary	5281	88.5	5891	81.4	+12
Other sector	171	2.9	171	2.4	0
Total	5969	100.0	7233	100.0	+21

The implications for the poor and other social groups

The SAM-based fixed-price multiplier model built for the study also permits analysis of disaggregated impacts of these changes on different household categories. As shown in Table 2:

- The overall impact (as reported earlier) is a 20% increase in household income;
- Both rural and urban populations benefit from flexible allocation, but the urban benefit more (22% versus 14%);
- the big winners (with gains between 18% and 24%) would be all four urban categories (self-employed, salaried, casual labor and other households) and non-agricultural rural people who are either self-employed or are laborers. These groups together comprise about 72% of the population;
- There are no big losers in absolute terms, but, relative to all others those employed in agriculture (either self-employed or laborers, comprising 28% of the population) would be in about the same position if flexible allocation procedures were followed as they would have been if sectoral allocations remained fixed.
- The impact on the poor is thus mixed:

  - The poorest of all groups (agricultural labor, who comprise 20% of the population) is the only group not to gain from the changes. This implies that in moving to more flexible allocation policies, it is important to consider mitigation measures for this important group.
  - The poor who are not in agriculture ("other" rural labor and urban casual labor, who together comprise 23% of the population) do well, with the income of both groups 20% higher if the flexible allocation policy is followed.

Table 2. Impact of flexible versus fixed allocations on the income of different employment categories.

Employment group	Population %	Population Millions	Total group income (bill Rs) Fixed	Total group income (bill Rs) Flexible	Per capita income (thousand Rs) Fixed	Per capita income (thousand Rs) Flexible	Difference between fixed and flexible (%)
Rural							
R1: Self-employed, non agricultural	7	5.4	438	521	81	97	19%
R2: Agricultural labor	20	15.4	191	187	12	12	−2%
R3: Other labor	6	4.6	147	179	32	39	22%
R4: Self-employed in agriculture	8	6.2	157	162	25	26	3%
R5: Other households	4	3.1	231	277	75	90	20%
All rural	44	33.9	1165	1325	34	39	14%
Urban							
U1: Self-employed	18	13.9	2538	3079	183	222	21%
U2: Regular wage salary	24	18.5	2131	2634	115	143	24%
U3: Casual labor	11	8.5	400	481	47	57	20%
U4: Other households	3	2.3	275	325	119	141	18%
All urban	56	43.1	5345	6519	124	151	22%
All rural and urban	100	77.0	6510	7844	85	102	20%

A program of water conservation in agriculture

Water use in the state (as in other parts of India) is dominated by agriculture. The question then arises – if we could only make agricultural water use a little more efficient, would this release enough water for other higher value purposes?

First, if the "fixed sectoral allocation" practice is followed, this would obviously have little positive impact, because the "released water" would still be assigned to agriculture. If, however, a program of water conservation were to be done in conjunction with the implementation of a flexible approach to water allocation, then such a program would have a large positive impact. These effects were simulated, based on the field experimental data, by assuming that the net amount of water used for growing paddy and sugarcane could be reduced by 25% (without affecting output). This would result in savings of about 1700 MCM of water per year, of which 1300 MCM would be used in agriculture and 400 MCM by the industrial and power sectors. This would result in an overall increase in GVA of Tamil Nadu by 98 billion Rs (1.4%). Of course, the cost implications as well as technology transfer activities need to be addressed separately.

Implications for policy

There are a host of specific "horror stories" which show that water scarcity is becoming a serious constraint to the growth of the Tamil Nadu economy, to the well-being of its people and to the environment. The numerous efforts at in-state and extra-state supply augmentation have yielded little. The state water policy of 2002 also gives high priority in water supply augmentation and conservation. It is now time for the Government of Tamil Nadu to re-focus its efforts, away from hoping that some new supply scheme will solve the problem and towards managing the limited water resources of the state so that water does not become a brake on economic growth. International experience suggests that a central step in maximizing "incomes per drop" and "jobs per drop" is to move away from command-and-control allocation procedures and towards more flexible procedures that improve water productivity, whereby water can move from low-value to high-value uses and where willing buyers can compensate willing sellers for the opportunity to use water.

This paper addresses the question – "Is this change worth making?" and answers the question with a resounding "yes", on almost all counts. There would be a major positive impact on the environment and a large positive impact on overall economic growth. The benefits of such growth would be shared by rich and poor, by urban and rural, with one large exception: Those who labor in agriculture will not benefit in the same way that all other employment groups benefit.

In the past, in many countries, including India, the response to such developments has been to assume that those who work in agriculture are doomed to this forever and therefore to pump in subsidies in a variety of ways to help farmers and agricultural laborers. This study is another piece of evidence that suggests that this is the wrong approach and that the right approach would be to pump in money which would facilitate the migration of people out of agriculture and into rural and urban non-agricultural livelihoods and which would provide safety nets as this massive transition takes place. This study, then, resoundingly answers "yes" to the question "Is it worth moving away from a command and control system of water allocation and towards a flexible allocation system?"

The "how to move towards such a flexible allocation system?" is not the focus of this study. It is, however, recognized that the actual means of achieving flexibility in water allocations will themselves incur costs – political, management and economic. It is important to assess the trade-offs between achieving higher value transfer and the political and economic costs of doing so. Political decision makers opting for reforms would however recognize that the number of gainers, directly and indirectly from flexible water allocation, are far greater than the number of losers. Further, political leaders will have to provide stakeholders with clear, understandable information on options and consequences. For example, farmers growing paddy will need to know that "selling" water to municipalities and industries gives them higher profits than using the water for growing paddy.

Moving towards such a system of allocation would require action on a number of fronts and comprehensive changes in water law. The most important challenge in moving towards such allocation policies lies in defining transferable and enforceable water use rights and in allowing willing sellers and willing buyers to exchange water through both leases and sales. Given the need to reduce transaction costs, investments would be required in creating control structures for transfer and delivery mechanisms including secondary and tertiary system improvements. These will have to be complemented by needed institutional arrangements.

It is worth noting that (as discussed in the introduction) the state of Tamil Nadu has made a tentative and incomplete start down this road in facilitating the transfer of water from paddy farmers in the AK aquifer to the city of Chennai. In many ways, the "flexible allocation" described above is a similar widening of this concept of allowing limited amounts of water to move from lower to higher-value uses throughout the state. What is now needed is to build on the initial AK experiment (specifically by dealing more effectively with the entitlements of farmers and ensuring that abstractions from the aquifer do not exceed the sustainable yield) and simultaneously to extend the idea state-wide so that the transfer of water from low- to high-value uses is facilitated and that those who give up their implicit water entitlements do so voluntarily in exchange for appropriate compensation. It is also desirable to extend the same concept beyond the borders of the state of Tamil Nadu, so that the state can obtain much-needed additional supplies from its neighbors. Again the keys will be the establishment of clear (state) entitlements and the development of mechanisms for the voluntary, compensated transfer of water from willing sellers to willing buyers.

There are some initial, tentative, experiments in this direction being undertaken in India. For example, urban authorities in the greater Delhi metropolitan area have recently concluded a deal which involves paying the Uttar Pradesh Irrigation Department the costs of lining about 45 km of canal, in return for an assured supply of water which is "saved" as a result. In Tamil Nadu, in addition to the Chennai experiment, another important development is the concession contract stimulated by the textile entrepreneurs of Tirapur, whereby a private operator will supply water to the industries of the town and domestic users.

As supplies become further stressed (and polluted) and demands increase to meet the needs of a growing population with growing expectations, it is essential for states to re-examine the approaches to water management, undertake serious analytical work and scenario analysis and devise management instruments that are economically sound, politically acceptable and technically feasible. In water constrained economies such as Tamil Nadu, this would mean protecting the quality and sustainability of available water sources while developing instruments to allow water to be used for increasingly higher values with the willing sellers having a safety net of compensation from the willing buyers.

Acknowledgements

This study was supported by the Bank Netherlands Water Partnership Program. The authors are grateful to C.R.Ranganathan and Narinder Singh for valuable assistance.

References

Bell, C., Hazell, P. & Slade, R. (1982). *The Project Evaluation in regional Perspective–A Study of an Irrigation Project in Northwestern Malaysia*. Johns Hopkins University Press.

Bhatia, R. & Malik, R. P. S. (2004). Indirect impacts of the multipurpose Bhakra Dam. In *Indirect Economic Impacts of Dams*. in Bhatia, R., Scatasta, M. & Cestti, R. (eds). The World Bank, Washington, DC.

Briscoe, J. (1997). *Water Resources Supply and Management Issues in Madras*. Memorandum, World Bank, Washington, DC (Mimeo).

Hazell, P. & Ramasamy, C. (1991). *The Green Revolution Reconsidered: the Impact of High Yielding Rice Varieties in South India*. The Johns Hopkins University Press, Baltimore.

Ortolano, L. & Cushing, K. K. (2002). Grand Coulee Dam seventy years later: What CAN we learn? *Water Resources Development*, *18*(3), 373–390.