Cost and Benefits of the National River Linking Project: An Analysis of Peninsular Links

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Abstract

Water, a critical component of food, livelihood and economic security, has always received a central place in India's investment portfolios. The investment in water transfers of the National River Linking Project (NRLP) is one of the biggest proposed in recent times. When and if completed, the NRLP forms a gigantic water grid covering most of South Asia. It envisages transferring 174 billion cubic meters (Bm^3) of water across 34 river links and will cost about US$120 billion (2000 prices). The proposed plan has aroused a large interest in recent public discourses. Hydrological feasibility, financial viability and social cost are the issues that dominate these public dalogues. This paper analyzes the cost and benefits of eight river links in the peninsular component, which include the main subcomponent of linking rivers of Mahanadi, Godavari, Pennar and Cauvery. Irrigation is the main beneficiary in this component and, en route, these links or canals account for 85% of the total water transfers to irrigation and domestic and industrial sectors in the command areas. However, our analyses show mixed results of financial viability of individual links. The main reason for this is low net value-added benefits from additional irrigation over and above the existing level of cropping and irrigation patterns. The proposed cropping patterns of these links generate much less net value-added benefits than the existing cropping and irrigation patterns. To make these links financially viable, they need to include high-value cropping patterns that, at least, generate as much benefit per unit area as fruits and vegetables.

Although some individual links show less than desirable net benefits, taken together the Mahanadi-Godavari-Pennar-Cauvery subcomponent gives a higher internal rate of return of 14% compared to a discount rate of 12%, and a high benefit-cost ratio of 1.3. However, many unknown factors or unavailable information in this analysis can alter the estimates of financial benefits and costs.

Introduction

The importance of access to water in India's national food security is well recognized. Access to irrigation was a critical determinant for the success of the green revolution, which transformed India's chronic food deficits in the 1960s to a state of food self-sufficiency in the 1970s. The effect of irrigation on productivity growth, as a direct input and as catalyst for other high-value agronomic inputs, continued and spread to vast rural landscapes. High productivity growth was indeed a major reason for livelihood security that decreased poverty in rural areas. Today, access to water is a vital component of national economic growth. However, with increasing population and urbanization with expanding industrial and service-sector economic activities, many regions in India are facing extreme physical to economic water scarcities (Amarasinghe et al. 2005). Water is physically scarce in southern and western India, where available resources are not adequate for further development without deleterious consequences to the environment. But, water is plenty in the east and northeast India, where floods damage agriculture and infrastructure, causing human misery year after year. The negative impact, due both to droughts and floods, will likely increase with climatic change (Gosain et al. 2008). Indeed, India is facing a water crisis. It is a crisis comprising scarcity, on the one hand, and plenty, on the other. The crisis needs to be urgently managed, and India is facing the dilemma of how to face this water crisis.

India’s proposed NRLP is claimed to be a part of a solution to the pending water crisis (NWDA 2008). It envisaged diverting surplus floodwater from the northeastern and eastern rivers to water-scarce south and west. The Brahmaputra, Mahanadi and Godavari are primarily the donors in the NRLP, while Krishna, Pennar and Cauvery in the south and Sabramati and Mahi in the west are the main recipients. Once completed, the project will impound water in reservoirs both in and outside India, transfer and distribute water through an extensive network of canals to irrigate more than 34 million ha, generate 34 GW of hydropower, meet domestic and industrial demands in many cities, recharge groundwater to relieve overexploitation, reduce flood damage, and create direct and indirect employment to many people in the water-recipient regions.

The NRLP has two major components: the Himalayan and the peninsular. The Himalayan component, with 16 river links, primarily facilitates the transfers of the surplus water in the east to the Ganga Basin and water-scarce basins in the west of Peninsular India. The peninsular component with 14 river links, mainly transport and distribute the surplus water to the water-scarce regions within the peninsular river basins. Both components will have about 3,000 storages to connect 37 rivers, and they will form a gigantic water grid, which South Asia has never witnessed in the history of water development. Yet, the NRLP plan drew wide criticism from a wide range of stakeholders, including the civil society, academia, environmental community, policy planners and politicians. The criticisms are partly due to its gigantism, in which the project costs colossal amounts of money when India badly needs investments for developing social and physical infrastructure and which brings enormous environmental damages by transporting water long distances displacing a large number of people and submerging large swaths of productive agricultural land, homesteads, forests, etc. Many people also argue that the economic benefits that NRLP generates will not be sufficiently high vis-à-vis the social and environmental costs that it creates. But, many of the arguments for and against the NRLP lack sufficient analytical rigor.

The research project, “The Strategic Analyses of National River Linking of India,” of the Challenge Program on Water and Food (CPWF) and the International Water Management Institute (IWMI) is trying to fill the void created by the lack of analytical rigor and informs the public better of the discourse on NRLP (CPWF 2005). The project also raises many strategic issues regarding the state of the water sector that India needs addressing for preventing a pending water crisis with or without the NRLP.

A water development project generally originates from a water futures assessment. The major source for NRLP was the scenario's assessment of the National Commission of Integrated Water Resources Assessment (NCIWRD 1999). But, the drivers, both exogenous and endogenous, of water demand and supply are changing rapidly. The publication "India's Water Futures: Scenarios and Issues" (Amarasinghe et al. 2009), discusses scenarios and issues that emanate from this fast-changing status of drivers. India has a large rural population with agriculture-dependent livelihoods. Meeting livelihood security of the rural masses and food security at the national level is the foremost priority of policy planners. As a result, many large water development projects have been proposed and implemented to date. However, the proposed NRLP is such a gigantic water grid that India and, for that matter, the whole of South Asia have never dreamt of implementing before. Thus, issues embedded in the NRLP are many, requiring more attention than previous water development projects. In the proceedings of the national workshop "Social, Hydrological and Environmental Issues of the National River Linking Project" (Amarasinghe and Sharma 2008) many issues related to the NRLP project are discussed.

This paper assesses the financial benefits and costs of some of the proposed peninsular links. The primary focus of the assessment is on irrigation benefits. Of all water transfers of the NRLP, irrigation is the major beneficiary. The benefit analysis in this paper focuses on the changes of India's irrigation landscape since the project proposal came into existence. Thus, we develop scenarios of benefit streams on the level of irrigation that could already be in the proposed command areas. After a brief introduction of the domain of analysis in the next section, we explain the methodology in detail in the section on methodology of benefit assessment. Then follows the section on the benefit and cost scenarios of the links in the study. Lasr, we conclude the paper with a discussion of issues arising out of this analysis for consideration for further analyses.

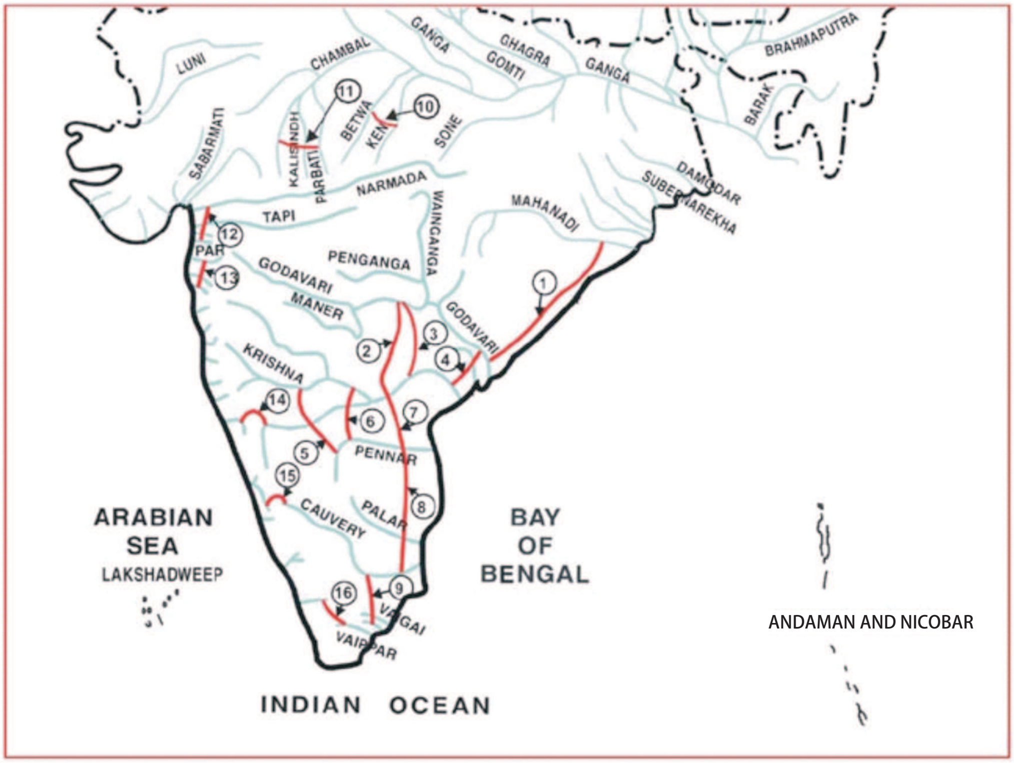
Links in the Study

This study assesses financial benefits of eight links in the peninsular component (Figure 1) that connect Mahanadi, Godavari, Pennar and Cauvery river basins. These include Link 1 connecting Mahanadi and Godavari, Links 2, 3 and 4 connecting Godavari and Krishna, Link 7 connecting Krishna and Pennar[1], Link 8 connecting Pennar-Palar-Cauvery and Link 9 connecting Cauvery to Vaigai and Gundai subbasins in Tamil Nadu. The full implementation of these links is largely dependent on water transfers between one another. Water transfer from Mahanadi to Godavari facilitates water transfer from Godavari to Krishna that, in turn, facilitates water transfer to Pennar, and then to Cauvery. Additionally, we include the link connecting Pamba to Achankvoil-Vaipar, transferring surplus water from Kerala to Tamil Nadu.

[1]Links 5 and 6 were not considered for this analysis. Water transfers through these links from Krishna to Pennar are only substitutes for the water transfers from Krishna to Pennar from the Nagarjunasagr-Pennar links.

Figure 1. River links in the peninsular component.

PROPOSED INTERBASIN WATER TRANSFER LINKS,
PENINSULAR COMPONENT



1. Mahanadi (Manibhadra) - Gadavari (Dowlaiswaram)*
2. Godavari (Inchampalli) - Krishna (Nagarjunasarar)*
3. Godavari (Inchampalli) - Krishna (Pulichintala)*
4. Godavari (Polavaram) - Krishna (Vijayawada)*
5. Krishna (Almatti) - Pennar*
6. Krishna (Srisailam) - Pennar*
7. Krishna (Nagarjunasagar) - Pennar (Somasila)*
8. Pennar (Somasila - Palar - Couvery (Grand Anicut)*
9. Cauvery (Kattalai) - Vaigai - Gundar*
10. Ken - Betwa*
11. Parbati - Kalisindh - Chambal*
12. Par - Tapi - Narmada*
13. Damanganga - Pinjal*
14. Bedti - Varda
15. Netravati - Hemavati
16. Pamba - Achankovil - Vaippar*

* Feasibility reports completed

Links in the analysis include:

- The uppermost link of the peninsular component links Mahanadi (Manibhadra) and Godavari (Dowlaiswaram) rivers. The primary objective of this link is to transfer surplus water of the Mahanadi Basin. While doing so, en route, this link provides water for irrigation, domestic purposes and industries and meets the water demands of the downstream from Dowlaiswaram in the Godavari Basin. The latter is only a substitute for the water transfers from Godavari to the Krishna Basin via three links upstream of Dowlaiswaram.
- Godavari (Inchampalli)-Krishna (Nagarjunasagar) is the uppermost link originating from the Godavari Basin and, en route, this link also supplies water for irrigation, domestic and industrial purposes, and then transfers water from Krishna to the Pennar Basin at Nagarjunasagar.

- Godavari (Inchampalli)-Krishna (Pulichintala) is the middle link originating from the Godavari Basin and, en route, this water provides only for irrigation and domestic and industrial purposes.
- Godavari (Polavaram)-Krishna (Vijayawada) is the lowermost link from the Godavari Basin. The primary objective of this link is to facilitate water transfer from Krishna to Pennar by way of substituting the water demand of Krishna below Vijayawada. This link also has major provisions for irrigation, and domestic and industrial purposes en route from the canal command.
- Krishna (Nagarjunasagar)-Pennar (Somasila) Link, one among the three links originating from Krishna to Pennar, provides water en route for irrigation and domestic and industrial purposes, and facilitates water transfer from the Pennar to the Cauvery Basin.
- Pennar (Somasila)-Palar-Cauvery Link, facilitating transfer of water received from Krishna to the Cauvery Basin,
- Cauvery (Kattalai)-Vaigai-Gundai Link, which transfers water from smaller basins of Cauvery. This link also provides water for irrigation and the domestic and industrial sectors.
- The last link in the study transfers water from Pamba to Achankvoil-Vaipar subbasins for irrigation, which is an independent component in the peninsular basins.

The eight links considered in this analysis transfer 61 Bm^3 of water, accounting for 35% of the total water transfers in NRLP and, en route, these canals provide 18.3 Bm^3 irrigation to 2.9 million ha (Mha) of culturable land and meet 3 Bm^3 of domestic and industrial needs.

En route, the command areas cut across 33 districts and include 0.256 Mha of croplands in six districts in Orissa, 1.4 Mha of nine districts in Andhra Pradesh, and 0.823 Mha of 17 districts in Tamil Nadu (Table 1).

According to feasibility reports prepared by the National Water Development Agency (NWDA 2008a-f), the total cost of supplying water to en-route commands of eight links is US$6,257 million (Table 2), which is 41% of the total cost. This is only the apportioned cost of water supply to en-route commands. For example, Mahanadi-Godavari diverts water not only for the en-route command but also for Godavari Delta. The latter is a substitution for the diversions from the upstream location in Godavari to the Krishna Basin. It also generates hydropower to be used outside the en-route canal. The total cost of the project is US$3.9 billion, of which the en-route command accounts for only 35%.

The total cost estimate of the eight links is US$15 billion, which is only 12% of the cost estimate of the whole NRLP project.

Table 1. Details of river links in the study.

	Name of link	Water transfers from the canals									
		Total	Down-stream diversion	En-route water distribution			En-route irrigated area distribution				
				Irrigation	Domestic and industrial	Losses	CCA[1]	Area of water receipts	Share of CCA	Districts in CCA	Share of CCA in districts
		Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	ha		ha		ha
1	Mahanadi (Manibhadra)-Godavari (Dowlaiswaram)	12,165	6,500	3,790	802	1,073	363,959	Orissa	256,770	Nayagarh	28,057
										Khurda	106,317
										Cuttack	20,448
										Puri	9,714
										Ganjam	92,091
										Gajapati	143
								Andhra Pradesh	88,578	Srikakulam	73,499
										Vizianagara	15,079
										Vishakapatnam	18,611
2	Godavari (Inchampalli)-Krishna (Nagarjunasagar)	16,426	14,200	1,427	237	562	255,264	Andhra Pradesh	255,264	Warangal	70,021
										Nalgonda	147,651
										Khammam	37,592
3	Godavari (Inchampalli)-Krishna (Pulichintala)	4,370		3,665		290	467,589	IRBC- AP	48,230	Warangal	24,115
										Khammam	24,115
								NSLBC-AP	6,900	Krishna	4,600
										Khammam	2,300
								NSLBC-LIFT-AP	203,369	Krishna	101,685
										Khammam	101,684
								NSLBC b.Tammi	137,975	West Godavari	137,975
								NSRBC -AP	71,115	Guntur	4,600
										Prakasam	66,515
4	Godavari (Polavaram)-Krishna (Vijayawada)	5,325	3,501	1,402	162	260	139,740	Andhra Pradesh	139,740	West Godavari	69,870
										Krishna	69,870

Table 1 (continued)

	Name of link	Water transfers from the canals									
		Total	Down-stream diversion	En-route water distribution			En-route irrigated area distribution				
				Irrigation	Domestic and industries	Trans-mission losses	CCA	Area of water receipts	Share of CCA	Districts in the CCA	Share of CCA in districts
		Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	(ha)		(ha)		(ha)
7	Krishna (Nagarjunasagar)- Pennar (Somasila)	12,146	8,426	3,264	124	332	581,017	Andhra Pradesh	168,017	Prakasam	84,008
										Nellore	84,008
								Andhra Pradesh	413,000	Nagarjunsagar RBC	413,00
8	Pennar (Somasila)- Palar-Cauvery (Grand Anicut)	8,565	3,855	3,048	1,105	557	599,000	Andhra Pradesh	283,553	Nellore	132,569
										Chittoor	150,984
								Tamil Nadu	315,447	Tiruvallur	34,492
										Vellore	61,218
										Kancheepur	44,657
										Tiruvannama	62,366
										Villupuram	72,702
										Cuddalore	37,052
										Pondicherry	2,962
9	Cauvery (Kattalai)- Vaigai-Gundar	2,252	-	1,067	185	115	452,000	Tamil Nadu	452,000	Karur	45,020
										Tiruchchirap	68,462
										Pudukkottai	72,489
										Sivaganga	65,120
										Ramanathapu	63,581
										Virudhunaga	65,959
										Thoothukudi	71,369
16	Pamba-Achankvoil-Vaipar	635	-	635	-	-	56,233	Tamil Nadu	56,233	Tirunelveli	30,765
										Tuticorin	386
										Virudhunaga	25,082

Note: CCA stands for cultivable command area

Sources: NWDA 2008a-h.

Table 2. Total cost of supplying water to en-route commands of the eight links.

	Name and no. of link in the peninsular component (see Figure 1)	Total cost[1] (Rs million)	Year of cost level assessment	Financial exchange rate of US$1 in Rs	Capital cost in million US$ (in 2003-04 constant prices)
1	Mahanadi (Manibhadra)-Godavari (Dowlaiswaram)	63,018	2003-04	46.0	1,370
2	Godavari (Inchampalli)-Krishna (Nagarjunasagar)	27,540	2003-04	46.0	599
3	Godavari (Inchampalli)-Krishna (Pulichintala)	50,460	2003-04	46.0	1,097
4	Godavari (Polavaram)-Krishna (Vijayawada)	14,839	1994-95	31.4	473
7	Krishna (Nagarjunasagar)-Pennar (Somasila)	8,806	1998-99	42.1	209
8	Pennar (Somasila)-Palar-Cauvery (Grand Anicut)	4,170	2003-04	46.0	1,472
9	Cauvery (Kattalai)-Vaigai-Gundar Link	26,730	2003-04	46.0	581
16	Pamba-Achankvoil-Vaipar	139,79	1992-93	30.6	457
	Total	242,597		334.1	6,257

[1] This cost estimate is based on the feasibility reports prepared by the NWDA (NWDA 2008a-h). These costs are assessed in constant prices of various years. The last column shows the cost estimates in constant 2003 prices.

Methodology of Benefit Assessment

We estimate financial benefit-cost ratio (BCR) and internal rate of return (IRR) of water supply to en-route commands of the eight links. The financial benefit-cost analysis indicates long-term financial viability of the proposed links. This is different from an analysis of social benefits and costs that assesses how a project affects the society in total. The incremental net benefits and costs to the participants, whom the project directly affects, is the basis for the financial analysis. The analysis of social and economic benefits and costs assesses the effect of the project on the national or regional economy and society. Indeed, for a project to be economically and socially viable, first it must be financially sustainable, and second the social and economic benefits should exceed the cost over the life span of the project.

The primary reason for focusing on a financial benefit-cost analysis in the study is data availability. We have a sufficiently accurate long-term secondary database for the assessment of net financial benefits of the en-route command. However, only limited information is available for estimating the social and environmental costs. In our analysis, first we estimate the net present value (NPV) of each link, which is the present value of net incremental value-added benefit that the project will accrue over its lifetime. Discounting the net incremental benefits of a base year over the project life span with an appropriate discount rate gives the NPV:

$$NPV = \sum_{t=0}^{N+N_0} \frac{(B_t - C_t)}{(1+r)^t}$$

where, B_t is the net value-added benefits in period t; C_t is the project cost in period t; r is the appropriate financial discount rate; N_0 is the number of years before the project providing intended benefits, and N is the effective life of the project. A positive NPV indicates that the investment is worthwhile for generating positive financial returns. We also estimate the Internal Rate of Return (IRR) to assess the discount rate at which the project is a financially viable venture. The IRR is the discount rate at which the NPV equals zero.

A major part of the water transfers of the links is for irrigation. Of the eight links, 76% of the water transfers to en-route command areas is for irrigation, and 10% for meeting domestic and industrial water needs (Table 1). Further, 14% is accounted for as transmission losses. Thus, a primary focus of this analysis is to estimate the net value-added benefits of crop production (B_t^{crops}). We estimate the net benefit of crop production of a link by aggregating the benefits over districts that intersect the link command area. Benefits of new irrigation on a district include net value-added crop output (NVACOUP) and the indirect benefits are generated through forward and backward linkages with increased irrigation. This paper mainly deals with estimation of direct benefits. However, we draw from the results of other benefit-cost studies of water transfers to estimate the indirect effects. Bhatia and Malik (2007) estimated a multiplier value of 1.9 for the Bhakra irrigation project in Haryana. This means that for every $100 of direct benefits that new transfers generate, another $90 is generated, for the region where the project is located as a multiplier effect. For smaller projects, the multiplier effect has a smaller value, ranging from 1.1 to 1.4. Since the proposed command areas of the links are relatively smaller than the Bhakra irrigation project, we assumed 1.4 as the multiplier effect for estimating indirect benefits. So,

$$B^{crops} = 1.4 \times NVACOUP$$

The feasibility reports (NWDA 2008 a-h) indicate that parts of the proposed command areas of many links do already receive irrigation from small surface water schemes. Given the recent trends of land use patterns, it is likely that groundwater irrigation has also spread to many parts of the proposed command area (Annex Table 1 for changes in land use patterns of 33 districts). For example, Bhaduri et al. (2008) estimated that more than 90% of some districts in the en-route command area of the Godavari (Polavaram)-Krishna (Vijayawada) Link at present use groundwater irrigation. In the Ken-Betwa, another smaller link in the peninsular component, groundwater irrigation could have expanded to 35% of the command area (Amarasinghe et al. 2008). Of the 33 districts in the eight links, groundwater-irrigated area has increased significantly between 1985 and 2005. Groundwater irrigation varies from 7 to 73% of the net irrigated area in Andhra Pradesh, and 20 to 86% in Tamil Nadu.

Thus, water transfers of new links contribute to increase NVACOUP in the command areas in two ways. They change, (a) cropping intensity and cropping patterns and increase crop output on the already irrigated portion inside the proposed command areas and, (b) the yield, cropping intensity and cropping patterns in the rain-fed areas of the proposed command.

The total net value-added output ($NVACOUP^{crops}$) in each link is:

$$NVACOUP^{crops} = \sum_{i \in districts} \left(\begin{array}{l} A_{io}\left(\sum_{j \in crops} (CP_j - CP_{ijo}^{IR}) \times (Y_{ij}^{IR} \times p_j - C_{ij0}^{IR}) \right) + \\ (A_i - A_{i0}) \times \left(\sum_{j \in crops} \left(\begin{array}{l} CP_j \times (Y_{ij}^{IR} \times p_j - C_{ijo}^{IR}) - \\ \qquad CP_{ijo}^{RF} \times (Y_{ij}^{RF} \times p_j - C_{ijo}^{RF}) \end{array} \right) \right) \end{array} \right)$$

where, i varies over districts in the command area and j varies over 11 crops or crop categories, including rice, wheat, maize, other cereals, pulses, oilseed, sugar, fruits, vegetables, cotton and other crops including fodder, etc. Also,

A_i - culturable command area of the link in the ith district,

A_{i0} - culturable command area of the link in the ith district irrigated in 2000,

CP_j - share of the area of crop j in the proposed cropping patterns,

CP_{ijo}^{IR} - share of the irrigated area of crop j in district i in 2000,

CP_{ijo}^{RF} - share of the rain-fed area of crop j in district i in 2000,

Y_{ijo}^{IR} - irrigated yield of crop j in district i in 2000,

Y_{ijo}^{RF} - rain-fed yield of crop j in district i in 2000,

C_{ijo}^{IR} - cost of cultivation of crop j in district i in 2000 under irrigation conditions,

C_{ijo}^{RF} - cost of cultivation of crop j in district i in 2000 under rain-fed conditions, and

p_j - average export price of crop j in 1999-2001.

The secondary data for this analysis were available from various sources. This includes the Directorate of Economics and Statistics (GOI 2008) for the trends of cropping and irrigation patterns at the district level and cost of production data at the state level: IWMI PODIUMSIM model (Amarasinghe and Sharma 2008) for irrigated and rain-fed crop yields at the district level; and the FAOSTAT database (FAO 2008) for the world export prices.

In addition to the increases in crop production, water transfers also generate other benefits in the form of hydropower generation, and water transfers to domestic and industrial sectors. For these benefits, we rely on the estimates in the feasibility reports (NWDA 2008a-h). They also give the capital costs of construction of the links.

Scenarios of NVACOUP

This study estimates net value-added benefits of crop production in en-route command areas under different scenarios of increases in cropping intensity. The main reason for this is the available information on current cropping or irrigation intensity in the proposed command areas. Feasibility reports do not show what part of the proposed command area is new, or already irrigated, or under rain-fed conditions. Therefore, we consider four scenarios of assessing NVACOUP.

Scenario I assumes that the proposed command area is a completely new addition to the crop production base. Essentially, this means no crop production exists at present on the proposed command area, and hence A_{io}=0, and CP_{ijo}^{RF} =0. Obviously, this scenario would give the highest crop production benefits with new water transfers.

Scenario II assumes that the proposed command area is completely under rain-fed cultivation at present, indicating only A_{io}=0. Additionally, we assume that the share of crop area in the command area at present is the same as the share of crop area in the respective districts under rain-fed condition.

Scenario III assumes that maximum cropping intensity in the command areas at present is the minimum of the existing and the proposed command areas. This scenario assumes that maximum annual cropped area at present within the proposed command area is the cropped area proposed under full irrigation.

- For example, the current cropping intensity in districts covering the Mahanadi-Godavari en-route command area is 152% (Table 3). But we assume the current cropping intensity as only 131%, which is the same as the proposed cropping intensity under full irrigation. Only, 57% of that area is irrigated at present.
- In the districts covering Godavari (Inchampalli)-Krishna (Pulichintala) Link command, the current cropping intensity is 140%. But the proposed irrigation intensity is only 110%. So, in Scenario III we assume only 110% existing cropping intensity for Godavari (Inchampalli)-Krishna (Pulichintala) Link command.

Scenario IV assumes that irrigation is already available for a part of the command area. Also, the share of crop area in the command area under irrigated and rain-fed conditions at present is the same as that of the districts intersecting the command (Table 3). For example, the current cropping and irrigation intensities in the command area of Mahanadi-Godavari Link are assumed to be the same as those of the districts covering the command areas. In this case, the current cropping and irrigation intensities are 157 and 47%, respectively. However, the proposed irrigation intensity in the command area is 137%. This allows a part of the command area to be rain-fed even after water transfers; and the irrigation intensity in the Mahanadi-Godavari Link is 20% of the culturable command.

In all these scenarios, we assume the following in NVACOUP estimation:

- Feasibility reports show that a significant part of the command area is allocated for crops other than the 10 crops or crop categories mentioned above. We use the maximum of net value-added in the 10 crops to estimate the net benefits of other crops. In most links, this is the net value-added benefits of fruits and vegetables (Annex Table 2).
- The secondary data of cost of crop production under irrigation and rain-fed conditions at the district level are not available for this analysis. Depending on the availability of data and estimation constraints, we use a regression analysis of the state-level data from 2001 to 2004 to estimate the cost of production. The dependent variable of the regression analysis is the cost of production per ha and the independent variable is the percentage of irrigated area of crops. Additionally, a dummy variable captures other differences between states. In sugarcane, the total area is almost completely irrigated in most states. Therefore, we use the cost of production of irrigated sugarcane in Andhra Pradesh for the current analysis (these items of information are given in Annex Table 2).

Benefits and Costs

As expected, Scenario I, with no crop production before water transfers, has the highest NVACOUP, generating $1,898/ha of gross crop area (GCA) of all links (Table 4). Scenario II, with only one-season of rain-fed crop before water transfers, has the next highest NVACOUP, i.e., $1,040/ha.

- In Scenario II, all canals, except those in the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link, have positive net benefits. The negative benefits in these canals are mainly due to small differences in yields under irrigated and rain-fed areas at present and changes in proposed cropping patterns. The proposed cropping patterns in the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link do not have rice or other crops, which dominate the cropping patterns at present. Thus, in spite of increase in area under fruits and vegetables, with the highest net benefit/ha of different crops at present, the decreases in rice and other crops in the proposed cropping patterns have decreased the total NVACOUP.
- If the proposed cropping pattern is the same as that existing at present, then the NVACOUP increases from a negative 262/ha to a positive 2,093/ha.

Scenario III has the next best NVACOUP, i.e., $613/ha. This scenario still generates negative benefits in the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link, due to changes in cropping patterns. If the proposed cropping pattern is similar to that existing at present, then NVACOUP in this link changes from a negative $719/ha to a positive $411 /ha.

Scenario IV has the lowest benefits, i.e., $279/ha. Three out of the eight links under this scenario have negative value-added benefits. This is again mainly due to differences in cropping patterns. If the proposed cropping pattern is similar to that existing at present, then NVACOUP of the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link will increase from a negative $860/ha to a positive $134/ha.

This shows that the selection of a proper high-value cropping pattern, even after irrigation transfers, should be a necessary condition for the links to generate positive net benefits. Any drastic changes from the present cropping patterns, especially from fruits/ vegetables and other high-value crops would not yield any crop production benefits in the proposed command areas. At present, fruits, vegetables, rice and sugarcane provide the highest value-added net benefit per ha of all crops (Table 2). For crop production to generate positive net benefits, the proposed cropping patterns should include a higher percentage of high-value crops. This is more important in the command areas, where yields of irrigated crops are not significantly higher than those of rain-fed crops.

Table 3. Existing and proposed cropping and irrigation patterns.

No.	Name of link (Figure 1)	Net command area		Rice	Maize	Wheat	Other cereals	Pulses	Oil seeds	Sugarcane	Fruits and vegetables	Cotton	Other	Total
				Cropping and irrigation patterns (%).										
1	Mahanadi (Manibhadra) Godavari (Dowlaiswaram)	363,959	%CA-2000[1]	74	2	0	4	35	15	3	8	4	8	152
			%IA-2000[1]	47	0	0	1	2	1	3	3	1	0	57
			%CA (= %IA) - proposed	73	1	0	1	17	21	0	7	1	11	131
2	Godavari (Inchampalli)-Krishna (Nagarjunasagar)	255,264	%CA-2000[1]	42	4	0	6	17	12	0	5	12	21	119
			%IA-2000[1]	41	1	0	0	0	3	0	2	2	0	50
			%CA (= %IA) - proposed	0	15	0	28	17	22	0	10	8	0	100
3	Godavari (Inchampalli)-Krishna (Pulichintala)	467,589	%CA-2000[1]	66	4	0	2	20	4	6	5	12	21	140
			%IA-2000[1]	64	1	0	1	0	2	5	2	2	0	77
			%CA (= %IA) - proposed	0	0	0	0	15	45	0	30	10	0	100
4	Godavari (Polavaram)-Krishna (Vijayawada)	139,740	%CA-2000[1]	91	2	0	0	21	2	9	5	10	14	155
			%IA-2000[1]	91	2	0	0	0	1	8	2	2	0	106
			%CA (= %IA) - proposed	48	6	12	12	15	18	6	21	6	6	150
7	Krishna (Nagarjunasagar)-Pennar (Somasila) Link	168,017	%CA-2000[1]	54	2	0	3	28	6	3	5	13	23	135
			%IA-2000[1]	54	0	0	2	1	3	2	2	1	0	66
			%CA (= %IA) - proposed	25	0	0	24	10	15	0	4	9	13	100
8	Pennar (Somasila)-Palar-Cauvery (Grand Anicut)	599,000	%CA-2000[1]	46	0	0	5	10	31	10	4	4	7	118
			%IA-2000[1]	45	0	0	1	1	11	10	2	1	0	72
			%CA (= %IA) - proposed	18	4	0	10	14	15	0	5	13	20	100
9	Cauvery (Kattalai)-Vaigai-Gundar	452,000	%CA-2000[1]	54	1	0	7	4	14	3	4	4	12	103
			%IA-2000[1]	36	0	0	0	1	4	2	2	1	0	46
			%CA (= %IA) - proposed	15	5	0	10	10	20	0	20	20	0	100
16	Pamba-Achankvoil-Vaipar	56,233	%CA-2000[1]	61	2	0	3	7	13	3	5	4	15	113
			%IA-2000[1]	43	1	0	1	2	5	2	3	3	0	59
			%CA (= %IA) - proposed	15	0	0	13	12	15	0	20	15	0	90

[1] - CA-2000 and IA-2000 mean cropped and irrigated areas in 2000.

Table 4. Net value of crop output before and after water transfers.

	Name and no. of link (Figure 1)	Net value of crop output per ha of gross cropped area ($/ha in 2000 prices)											
		Scenario I			Scenario II			Scenario III			Scenario IV		
		Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change
1	Mahanadi-Godavari	0	948	948	622	948	326	668	948	280	703	864	161
2	Godavari–Krishna (Nagarjunasagar)	0	972	972	1,233	972	-261	1,681	972	-709	1,677	870	-807
3	Godavari-Krishna (Pulichintala)	0	2,792	2,792	1,125	2,792	1,667	1,672	2,792	1,120	1,651	2,114	463
4	Godavari-Krishna (Vijayawada)	0	1,874	1,874	697	1,874	1,177	1,357	1,874	517	1,360	1,834	474
7	Krishna (Nagar.)-Pennar (Somasila)	0	1,748	1,748	1,069	1,748	678	1,662	1,748	85	1,764	1,399	-365
8	Pennar (Somasila)-Palar-Cauvery	0	2,398	2,398	518	2,398	1,880	1,094	2,398	1,304	1,097	2,085	988
9	Cauvery (Kattalai)-Vaigai-Gundar	0	1,895	1,895	1,026	1,895	869	1,416	1,895	479	1,421	1,851	429
16	Pamba-Achankvoil-Vaipar	0	1,943	1,943	944	1,943	999	1,567	1,943	375	1,600	1,624	24
	All links	0	1,898	1,898	869	1,898	1,028	1,297	1,898	601	1,320	1,654	335

Net Present Value (NPV) and Internal Rate of Return (IRR)

In estimating NPV and IRR, we assumed a 12% annual discount rate, a 10-year construction period, project life span of 50 years and 10% of the capital cost as operation and maintenance costs. Total net value-added benefits of water transfers include:

- Net value-added benefits of crop production due to irrigation water transfers.
- Benefits of domestic and industrial[2] water transfers.
- Hydropower generation.[3]
- Indirect benefits of water supply assessed through a multiplier value, which we have taken as 1.4.

The net value-added benefit of a link is 1.4 times the net value-added crop output and domestic, industrial and hydropower benefits. The data show the percentage share of water supply and contribution to net value-added benefits by the irrigation, domestic and industrial sectors (Table 5). Clearly, a major part of the water deliveries is for irrigation. Of the eight links in this study, 85% of the water deliveries is for the irrigation sector, and 8 and 7% for domestic and industrial sectors, respectively. The contribution to net value-added benefits varies with existing extent of cropped and irrigated area. Scenario I has the highest contribution of irrigation to net value-added benefits. This contribution decreases from 88 to 62% from Scenarios I and IV.

The NPV, IRR and BCR of different links are given in Table 5. The results indicate the following:

- Under Scenario 1, all links except the Pamba-Achankvoil-Vaipar Link, have a significantly high IRR (16-39%) and BCR (1.3-6.9), showing that investments in the en-route canal command are financially viable. However, financial viability decreases with the assumption on existing cropped and irrigated areas in the proposed commands.
- If the en-route command at present has only rain-fed cropping (Scenario 2), then all links, except the Godavari (Inchampalli)-Krishna (Nagarjunasagar) and Pamba-Achankvoil-Vaipar links are financially viable. The proposed cropping pattern is the major reason for financial nonviability. If this link also has a high-value cropping pattern it can also be a financially viable option. If the proposed cropping patters are similar to those existing now, the BCR and IRR of the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link under Scenario 2 increase between 2.0 and 20%.
- A major part of the proposed command areas in all links already has some cropped area, and within that some irrigation. Scenarios III and IV correspond to these conditions. Under these scenarios, the IRR of all links, except the Godavari (Inchampalli)-Krishna (Nagarjunasagar), Krishna (Nagarjunasagar)-Pennar (Somasila) and Pamba-Achankvoil-Vaipar links, are more than the discount rate and BCR is more than 1, indicating that they will be financially viable investments with the projected benefit streams.

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[2]Benefits of domestic and industrial supply of all links are assessed at 5.00 and 14.50 Rs/m^3, respectively, of water deliveries, the rate used for assessing Godavari (Inchampalli)-Krishna (Nagarjunsagar) Links.
[3]Hydropower benefit is assessed at 1.67 per unit of kWh, the prevailing average rate per unit in Andhra Pradesh (NCAER 2009).

- These links whose proposed cropping patterns are quite different from those existing now have low irrigation benefits, low NPV and lower IRR and BCR. If the proposed cropping patters are similar to those existing now, the IRR and BCR of the Godavari (Inchampalli)-Krishna (Nagarjunasagar) Link under Scenario III increases to 14 and 1.1%, respectively. But the net benefits under Scenario IV still do not exceed the cost (BCR=0.7). With high-value cropping patterns, the Krishna (Nagarjunasagar)-Pennar (Somasila) Link can also generate large net benefits, high IRR and BCR.

Thus, it is clear from the analysis that projected benefits of individual links depend on the extents of cropping and irrigation that exist at present and the proposed cropping patterns in en-route command areas. If the proposed cropping patterns have substantial high-value crop areas, which at least give the net benefits as in fruits and vegetables, new investments on water supply in individual link commands are financially viable.

However, water transfers between links in the Mahanadi-Godavari-Pennar-Cauvery subcomponent are dependent on one another. Thus, it is more appropriate to assess benefits and costs for the whole component than for the individual links. When all links are considered together, the net value-added benefits still exceed the cost. The IRR and BCR are significantly higher than the discount rate (12 %) and 1 respectively, under Scenarios I and II; 19 and 1.7%, respectively, under Scenario III, and 15 and 1.3%, respectively, under Scenario IV. This shows that with proper cropping patterns, the aggregate net benefits of en-route commands in the Mahanadi-Godavari-Pennar-Cauvery component exceed the cost, and the investments are financially viable.

Does this mean that the subcomponent of linking Mahanadi, Godavari, Pennar and Krishna as a whole, is a financially viable investment? This is a difficult question to answer from the above results due to many reasons. We discuss these issues next.

Table 5. Share of water deliveries and contribution to net value-added benefits from domestic (DOM), industrial (IND), hydropower generation (HYP) and irrigation (IRR) sectors and net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR).

No. and name of link in Figure 1		Share of water deliveries (%)			Contribution to net value-added benefits (%).											
					Scenario 1				Scenario 2				Scenario 3			
		DOM	IND	IRR	DOM	IND	HYP	IRR	DOM	IND	HYP	IRR	DOM	IND	HYP	IRR
1	Mahanadi-Godavari	8	9	83	6	22	1	70	10	33	2	55	13	43	2	42
2	Godavari-Krishna (Nagarjunasagar)	6	8	86	4	14	0	82	na	na	na	na	na	na	na	na
3	Godavari-Krishna (Pulichintala)	4	6	90	1	5	0	93	2	9	0	89	3	12	1	84
4	Godavari-Krishna (Vijayawada)	10	0	90	4	0	0	96	6	0	0	94	14	0	0	86
7	Krishna (Nagar.)-Pennar (Somasila)	4	0	96	5	0	0	95	11	0	0	89	49	0	0	51
8	Pennar (Somasila)- Palar-Cauvery	15	12	73	4	10	0	86	5	12	0	83	7	16	0	77
9	Cauvery (Kattalai)-Vaigai-Gundar	5	10	85	1	4	0	95	2	9	0	89	3	15	0	82
16	Pamba-Achankvoil-Vaipar	0	0	100	0	0	30	70	0	0	45	55	0	0	69	31
	All links	8	7	85	3	8	0	88	5	13	0	81	8	21	1	71

Table 5 (continued)

Name and no. of link	Contribution (%)				NPV (US$), BCR (number) and IRR (%)											
	Scenario 4				Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	DOM	IND	HYP	IRR	NPV	BCR	IRR	NPV	BCR	IRR	NPV	BCR	IRR	NPV	BCR	IRR
Link 1	15	51	3	32	1,404	2.0	21	446	1.3	16	20	1.0	12	-201	0.9	10
Link 2	na	na	na	na	721	2.2	22	-674	na	na	-1,180	na	na	-1,464	na	na
Link 3	5	19	1	75	5,090	5.6	35	2,760	3.5	29	1,627	2.5	24	654	1.6	18
Link 4	15	0	0	85	1,348	3.9	30	917	3.0	26	88	1.2	14	64	1.1	14
Link 6	na	na	na	na	1,152	6.6	38	356	2.7	25	-85	0.6	5	-516	na	na
Link 7	7	17	0	75	5,867	5.0	34	4,491	4.1	31	2,964	3.0	27	2,605	2.8	25
Link 8	3	16	0	81	3,414	6.9	39	1,360	3.4	28	579	2.0	21	505	1.9	20
Link 10	0	0	96	4	156	1.3	16	-56	0.9	10	-195	0.6	5	-273	0.4	na
All links	10	27	1	62	19,360	4.3	32	9,844	2.7	25	4,084	1.7	19	1,653	1.3	15

Note: 1, "na" indicates values are negative or not defined; aggregate based on all links except Pamba-Achankvoil-Vaipar.

Sour ce: Authors' estimates.

Discussion and Conclusion

We discuss a few issues here that arise from our analysis of benefits and costs or from lack of detailed information on the proposed links.

- According to the NRLP plan, a substantial part of the proposed water transfers in the Mahanadi-Godavari-Pennar-Cauvery subcomponent is only a substitute for the water transfers out of the upstream of river basins. For example, 6,500 Mm^3 of water transfers in the Mahanadi-Godavari Link are allocated to meet the demand downstream of the Godavari River. If not for water transfers to Krishna from the upstream of Godavari, the above quantity for downstream use would anyway be available from the surplus water of Godavari. Since this quantity is only a substitution, what additional net output would this generate and account for the project benefits? A similar situation is applicable for the water transfers to the Krishna Delta through the Godavari (Polavaram)-Krishna (Vijayawada) Link, which amounts to another 3,500 Mm^3.

  The water transfers of these two links as substitution is 10,000 Mm^3, and this volume would be more than half the water delivered to en-route command areas. An important question here is whether the net value-added benefits from the water transfers as substitution are more than the value transfers can generate if they are new transfers to a region. Theoretically, this cannot generate any net value-added benefits in Godavari as it is a water-surplus basin. However, the water transfers to the Krishna Delta could add value as it is a water-scarce basin. However, it is not clear from the feasibility reports how this allocation would be used in the Krishna Delta.

  If the total capital cost of the Mahanadi-Godavari Link is added to the cost component, the IRR of all links under Scenarios III and IV will decrease to 13 and 10%, respectively.

- It is not completely clear whether the water transfers from Brahmaputra to Mahanadi basins through the Himalayan Links are necessary for the fully operational Mahanadi-Godavari-Krishna-Pennar subcomponent. If they are, then a part of the capital cost of the Himalayan Links should also be included in the peninsular subcomponent in this analysis. Therefore, the capital cost estimates of the links used in this study could be substantially lower, and hence the estimates of IRR and BCR could be higher. For instance, the Manas-Sankosch-Tista-Ganga, Ganga-Damodar-Subernarekha, and Subernarekha-Mahandi links in the Himalayan component facilitating water transfers from Brahmaputra to Mahanadi cost about US$19 billion. In fact, the total cost of these three links is 30% more than the total cost of the eight links in this study, and 200% more than the cost of water transfers to eight en-route link commands. Thus, adding a portion of the Himalayan component capital cost could very much escalate the total cost used in this analysis. Under such a scenario, the BCR and ICR will decrease drastically.

- A substantial part of the irrigation deliveries and the transmission losses in canals contribute to groundwater recharge. This recharge could help expand groundwater below the command areas and links. In this study, the extent of groundwater irrigation that will originate from this groundwater recharge and the resulting benefits are not clear. If these are known, it is certainly an indirect contribution for the benefit streams, and with regional multipliers the net value-added could be much higher. If we include these benefits, the BCR and IRR of the subcomponent could increase.

- The new reservoirs and canals will submerge large parts of forest and agricultural land and displace populations. Forests contribute to livelihoods of many people, especially the tribal population living there. They are the majority who will be displaced due to water transfers. The flora and fauna of the submerged lands were means of income for many people. This analysis has not considered the financial losses due to the submergence of lands, displacement of people and environmental impacts on the riverine environment. Such financial losses can decrease the net value-added benefits, reducing IRR and BCR.
- New reservoirs impound large quantities of water and affect the river flows downstream. Vladimir et al. (2008) show that many peninsular river basins could be perceived to have more surpluses than what they actually have. If these perceived surpluses are impounded and transferred out of the basin, they could badly affect river flows downstream. River flows in the downstream support the livelihoods of many people, especially in terms of inland navigation, fishing, tourism, etc. Thus, impounding could financially affect riverine populations directly and others indirectly. If these financial losses are included, IRR and BCR could decrease.

Our analysis indicates that if new water transfers only bring new lands into cultivation, the benefits are immense. Also, if water transfers are only used for irrigating the existing rain-fed lands, the net value-added benefits could still exceed costs by several factors. However, in reality this is not the case. The proposed command areas for irrigation in many river links already have some cropped areas and, in some cases, irrigated areas too. The financial viability of these links depends on the proposed cropping patterns. They require irrigating substantially high-value crops such as vegetables and fruits. The IRR and BCRs of links depend on many factors other than net value-added benefits of irrigation, domestic and industrial sectors in the en-route command areas and hydropower generation. These include hydrological factors related to groundwater recharge and benefits; environmental factors due to area submergence and loss of river flows, and social factors due to displacement, resettlement and rehabilitation of project-affected people. They need to be considered for a proper financial and social benefit-cost analysis framework.

Annex

Table 1. Changes in net irrigated area as a % of net sown area, and net groundwater irrigated area as % of net irrigated area in Andhra Pradesh and Tamil Nadu.

State	District	Net irrigated area - % of net sown area								Net groundwater irrigated area - % of net irrigated area							
State and district		1971	1975	1980	1985	1990	1995	2000	2005	1971	1975	1980	1985	1990	1995	2000	2005
Andhra Pradesh	Adilabad	5	6	7	8	10	12	15	16	11	12	15	19	29	44	42	59
	Anantapur	13	15	14	14	15	14	14	11	38	45	48	56	59	68	71	70
	Chittoor	31	31	30	29	32	34	40	39	45	48	59	62	65	71	82	69
	Cuddapah	26	30	29	27	31	31	36	34	48	46	57	60	62	72	79	71
	East Godavari	63	64	65	64	62	63	65	65	4	7	7	11	10	17	20	21
	Guntur	48	50	54	57	58	54	59	59	2	4	4	4	6	9	11	15
	Karimnagar	22	29	32	40	60	68	69	76	47	46	50	46	52	66	62	56
	Khammam	16	20	21	30	39	40	42	42	14	10	18	15	21	26	29	37
	Krishna	64	66	66	72	72	68	68	66	6	6	7	7	8	11	12	16
	Kurnool	10	10	12	13	17	18	20	22	9	11	13	15	26	40	47	46
	Mahabubnagar	9	13	14	10	19	17	20	23	28	29	37	58	55	79	81	70
	Medak	15	20	22	23	31	27	30	29	22	27	42	48	54	77	87	80
	Nalgonda	20	28	27	27	35	38	40	46	18	18	26	25	37	47	53	53
	Nellore	62	64	69	74	81	82	76	77	16	21	26	30	28	32	37	36
	Nizamabad	34	46	47	49	59	59	67	70	12	12	19	22	37	67	68	72
	Prakasam	19	23	25	28	33	34	36	29	32	28	26	23	27	33	37	24
	Rangareddy	13	13	14	13	22	18	26	22	56	54	67	72	75	88	90	93
	Srikakulam	57	55	55	60	57	56	58	54	2	2	1	7	4	8	8	7
	Visakhapatnam	34	33	36	37	39	36	33	31	8	5	3	5	11	14	11	14
	Vizianagampuram	41	40	40	42	43	43	41	39	4	2	1	6	9	10	11	7
	Warangal	21	27	27	37	55	60	59	69	27	24	36	54	58	70	75	73
	West Godavari	75	77	77	81	81	82	82	83	16	17	20	21	25	34	37	39
Tamil Nadu	Chengaianna	72	76	81	82	73	81	86	85	18	28	37	48	50	53	52	61
	Coimbatore	36	40	47	42	41	47	55	52	50	55	56	56	50	55	59	56
	Kanyakumari	40	34	35	35	34	35	36	35	1	1	1	5	5	5	6	6
	Madurai	34	33	43	38	42	47	49	46	41	49	52	53	55	61	64	69
	North Arcot\ Ambedkar	50	48	46	48	39	50	56	56	49	52	65	66	86	70	78	80
	Ramanthapuram	37	40	41	37	40	41	47	43	15	17	19	25	26	26	28	26
	Salem	22	21	27	22	27	32	37	53	66	73	76	74	80	83	82	86
	South Arcot	50	57	59	51	50	55	63	90	34	45	53	50	65	67	67	70
	Tanjavur	83	84	83	84	84	78	88	65	2	2	2	3	8	5	3	7
	The Nilgris	1	0	1	1	1	1	2	2	0	30	15	22	6	7	6	6
	Tiruchirapalli	31	31	39	33	34	36	46	54	30	30	35	37	40	51	57	67
	Tirunelveli	34	33	40	37	39	44	44	41	39	41	39	43	39	42	44	44

Note: Highlighted rows are districts that include en-route command areas in this study.

Table 2. Cost of cultivation, crop yields and net value-added benefits/ha for different crops.

Factor and link name	Irrigated (IR) or rain-fed (RF) conditions	Crops							
		Rice	Maize	Other cereals	Pulses	Oil crops	Sugarcane	Fruits and vegetables	Cotton
Cost of cultivation ($/ha)	IR	439	268	257	337	329	628	748	381
	RF	195	183	227	81	310	628	505	77
Crop yield (tonnes/ha)									
Mahanadi-Godavari	IR	1.36	2.01	0.49	0.23	0.77	3.79	16.81	0.34
	RF	0.71	0.57	0.27	0.21	0.32	2.56	11.30	0.26
Godavari-Krishna	IR	2.60	4.00	1.36	0.57	1.21	4.85	17.30	0.34
	RF	1.50	2.43	0.44	0.39	0.56	3.15	11.49	0.28
Godavari (Inchampalli)-Krishna (Pulichintala)	IR	3.14	5.24	0.79	0.61	1.46	5.39	17.30	0.37
	RF	1.50	2.82	0.77	0.70	0.67	3.49	11.49	0.27
Polavaram-Vijayawada	IR	3.14	5.55		1.11	1.81	5.48	17.30	0.37
	RF		3.20	1.80	0.92	1.04	3.55	11.49	0.27
Krishna (Nagarjunasagar)-Pennar (Somasila)	IR	3.19	6.76	0.92	0.70	1.72	5.04	17.30	0.35
	RF		4.12	0.27	0.59	0.80	3.27	11.49	0.28
Pennar (Somasila)-Palar-Cauvery (Grand Anicut)	IR	3.27	1.87	3.06	0.54	1.71	7.52	16.56	0.38
	RF	1.98	2.55	1.68	0.61	0.85	2.80	8.43	0.27
Cauvery (Kattalai) -Vaigai-Gundar Link	IR	3.09	1.40	2.62	0.37	1.57	9.86	16.06	0.41
	RF	1.06	0.97	1.08	0.49	0.97	3.14	11.05	0.28
Pamba-Achankvoil-Vaipar Link	IR	3.55	1.31	3.07	0.37	1.44	10.57	15.54	0.38
	RF	1.00	0.80	1.61	0.51	0.95	3.14	10.68	0.23
Export price ($/tonne)		375	176	203	499	559	267	530	1,100
Net value-added benefits ($/ha)									
Mahanadi (Manibhadra)-Godavari (Dowlaiswaram)		1	170	14	-245	228	329	2,676	-214
Godavari (Inchampalli)-Krishna (Nagarjunasagar)		170	192	155	-166	346	455	2,838	-238
Godavari (Inchampalli)-Krishna (Pulichintala)		370	343	-26	-305	423	507	2,838	-199
Godavari (Polavaram)-Krishna (Vijayawada)		933	328	-396	-161	409	516	2,838	-196
Krishna (Nagarjunasagar)-Pennar (Somasila)		951	380	102	-201	499	473	2,838	-230
Pennar (Somasila)-Palar-Cauvery (Grand Anicut)		241	-204	249	-291	466	1,263	4,071	-191
Cauvery (Kattalai)-Vaigai-Gundar		515	-10	281	-316	321	2,009	2,418	-164
Pamba-Achankvoil-Vaipar		714	6		266	-328	257	2,198	2,332

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