Benefits of Irrigation Water Transfers in the National River Linking Project: A Case Study of Godavari (Polavaram)-Krishna Link in Andhra Pradesh

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Introduction

The Comprehensive Assessment of Water Management Report of the International Water Management Institute (IWMI) states that presently one third of the world population face some form of water scarcity (Rijsberman 2006). Several hydrological projections have also indicated that in the future, water availability may plummet to a point where it intensifies water-scarcity, and may even become a global threat to human development (Barbier 2004). Such a widening gap between the demand and supply of freshwater has prompted the Consultative Group on International Agricultural Research to initiate a Challenge Program on Water and Food (CPWF) and address the concerns about global food and water scarcity.

Many articles (Howe et al. 1986: Saleth 2001) have identified two fundamental ways to meet water-scarcity. First, water-scarcity can be mitigated by managing the demand for water. Water demand management (WDM) offers the potential to increase water availability by coupling proper water allocation with efficient use. However, mitigating water scarcity only by managing demand has its limitations. Its implementation has been fraught with numerous difficulties and constraints, most of which relate to the lack of enabling environment and institutional capacity for the adoption and implementation of Integrated Water Resources Management (Ncube et al. 2006).

Second, water scarcity can be met by augmenting the supply of water. Inter-basin water transfer often is viewed as an instrument to mitigate water scarcity through the diversion of water from a water-surplus part of a given river basin system to one or more water-deficit areas in another river basin. (Bhaduri 2005). The main objective behind the implementation of such projects is to continuously meet the existing and future water demand in the face of decreasing relative water availability. Creating new sources to augment water supply requires large investments and effective institutions for allocating water.

As part of the CPWF program, International Water Management Institute (IWMI) has undertaken a study to examine the viability of inter-basin water transfers in meeting water scarcity in water-deficient zones. The paper particularly explores the benefits of surface water augmentation in the agricultural sector.

The primary focus of the paper is India's National River Linking Project (NRLP). The choice of the case study is well justified in the sense that India is no exception to the general global trend of rising demand for freshwater. There is little doubt to the popular belief that access to freshwater availability in India has depleted over the years and, is likely to worsen in the coming years. The per capita water availability of 5,400 cubic meters per person in 1950 has decreased to 1,900 cubic meters per person in 2000 (Amarasinghe et al. 2005). Added to this, there has been a large regional spatial variation in different river basins in terms of water and food availability. As a consequence of spatial variations in different river basins, the Government of India has proposed several inter-basin transfer schemes. The project has the specific aim of diverting 'surplus' water from the Himalayan rivers in the north and east to water deficit areas in the peninsular and western India for development uses, e.g., irrigation, urban water supply, industrial use and hydro-electricity.

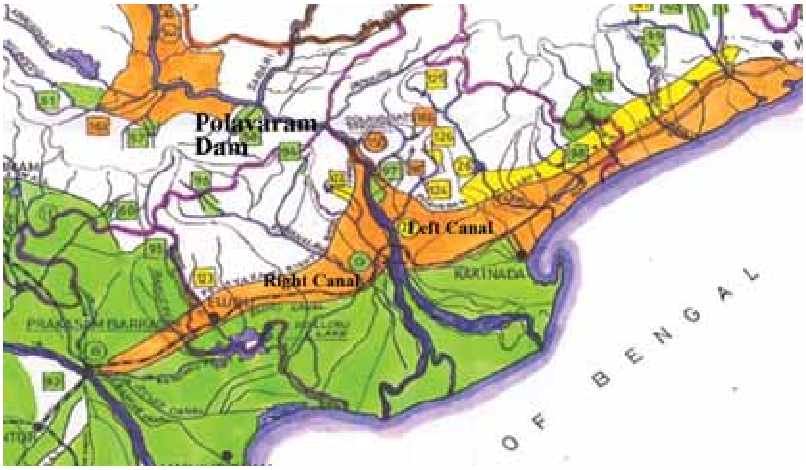
The National Water Development Agency (NWDA) of India has identified 30 Himalayan and peninsular rivers for such inter-basin water transfers (NWDA 1999). The Himalayan component consists of 14 links that involves transfers from the Ganges-Brahmaputra-Meghna basins, while in the peninsular component the water transfers would take place among 16 rivers that include the Mahanadi, Godavari, Krishna, Pennar, and Cauvery river basins. Among the peninsular component, the Godavari River has been considered as the sizeable surplus, and it is proposed that this river will transfer its surplus water to the Krishna, Pennar and Cauvery river basins. The paper illustrates the Godavari Link, and explores the potential economic benefits of the link for the agricultural sector. The scope of the study is confined to the agricultural sector as much of the water is used for agricultural purposes.

The Polavaram Project

The Godavari is the second largest river basin in India with about 320,000 km^2 of catchment area, and has been considered as the surplus basin for transferring water to the Krishna River basin. The water diversion is planned to take place entirely within the State of Andhra Pradesh using a dam to be constructed at Polavaram; and then through a 174 km long canal (right main canal) running westward to connect the Krishna River. It has been envisaged by the government authorities that the water diversion will provide irrigation to around 0.14 million ha of cultivated land, besides the transfer of 80 tmc of Godavari waters to the Krishna River (NWDA 1999).

Apart from establishing the Godavari Krishna Link, the Government of Andhra Pradesh has also designed the Polavaram Water Diversion Project so that it could be developed into a multi- purpose project. The plans of the project intend to use the diverted water from the Godavari River to provide irrigation benefits to a cultivated command area of 0.175 million hectares in the upland areas of the eastern side of the command area, in addition to supplying water to the city of Visakhapatnam for domestic and industrial purposes. The water transfer will take place through a 208 km long canal running eastwards towards the city of Visakhapatnam (see Figure 1).

Figure 1. Proposed command area map of the Polavaram Dam.



Why Does Andhra Pradesh Need a Polavaram Project?

A perennial shortage of freshwater resources for agriculture, industry and domestic purposes has prompted the Government of Andhra Pradesh to explore in its own way suitable methods to harness the available surface waters. Certain recent observations of irrigation data from Andhra Pradesh suggest that in the past decade, irrigation through surface water sources has largely been overtaken by groundwater irrigation. Subsidized electricity charges and the timely availability of water have encouraged farmers to buy water pumps and exploit the groundwater resource extensively. The consequence is reflected in the falling water tables. The current situation turns out to be double whammy for the state government, in that the government has to continue to pay the subsidies, while depth to groundwater continues to increase. (Narayanmoorthy et al. 2005).

The Government of Andhra Pradesh has spent a considerable amount of money for irrigation and other irrigation reforms. Since the last decade the spending on irrigation is between Rs. 1,500-Rs. 2,000 crores per year. The government's efforts notwithstanding, there has been little improvement in surface irrigation by the government source. Given the urgent need to meet the irrigational water demand, the government has planned to construct few dams and several lift irrigation schemes. The Polavaram Project, embarked upon by the Government of Andhra Pradesh is one such attempt. Presently, much of the water of the Godavari River flows into the Indian Ocean; in that government agencies estimate that around 644 tmcft (18 billion m^3) of water is currently not being utilized from the Godavari, and flows into the sea. Hence, the Government of Andhra Pradesh wants to capture a part of this unused water by constructing a dam at Polavaram.

Objective of the Paper

The research paper contributes in assessing the benefits of irrigation from the proposed Polavaram Dam. Many argue that a major proportion of the economic benefits of the dam could be realized from agriculture, and this is evident from the government's proposal, which indicates that nearly 64 % of the water from the River Godavari will be diverted for irrigation purposes only. The research paper attempts to address the question – how additional surface irrigation facility would help farmers to increase agricultural productivity.

The contribution of the research paper is not confined to direct irrigation benefits only. The paper also raises other hydrological concerns about the potential role of surface water irrigation in cases, where groundwater has been the dominant form of irrigation. The issue is very relevant and much talked about, as groundwater irrigation contributes 67 % of the net irrigated area of the country. Also governmental data sources reveal that in 1997 more than 50 % of cultivable area was irrigated from groundwater sources in the proposed command area of the Polavaram Dam (NWDA 1999). Our research studies indicate that presently groundwater depth is rising in many regions of the command area, and this imposes a severe constraint for the farmers on their crop choice, yield, cost of inputs and agricultural income. The issue is relevant in assessing the benefits of surface water irrigation and particularly considering that surface irrigation could facilitate groundwater recharge, reduce the stress on groundwater resources, and thereby help farmers in increasing the net value of groundwater irrigated land.

Past studies, related to the cost benefit analysis of surface irrigation projects, reveal a trend which suggests that the farmers grow mostly water-intensive crops, for instance, paddy, with the introduction of surface water irrigation. Thus, another issue of importance is whether the farmers who are growing high-value crops using costly groundwater would shift to low-value water-intensive crops such as paddy with surface irrigation. Several studies indicate that increases in productivity through canal irrigation are greater with multi-cropping and the cultivation of more profitable water-intensive cash crops such as sugarcane (Singh 2000). We researched whether surface irrigation would set a broader choice option for farmers in terms of crop diversification.

Livestock is an important source of income for the livelihood of farmers. The study also attempts to assess the livestock benefits that may be generated from the water diversion at Polavaram.

We have relied on the farm level primary survey data to assess the irrigation and livestock benefits of the water transfer, and to answer such questions as discussed above. A sample of 1,000 farmers was selected in the proposed command area, adjacent command area and in the rain-fed areas to evaluate the irrigation benefits.

The structure of the paper is organized as follows - in the next section we briefly explain the methodology in computing the ex ante benefits from the water diversion at Polavaram, after which in the following section, we describe the sampling plan and technique, and in the final section we explore the characteristics of the region.

Methodology and Data

Any assessment of the economic value of surface water generally begins with decisions that define the conceptual and empirical domain of the valuation (EPA 1995). Given an ex ante standing of the Polavaram Project, we define a reference condition for valuation as the existing agricultural and irrigation condition of the proposed irrigation command area, and the expected condition as that of a nearby surface irrigation command area. We, then, define the change in the net value per hectare of land as the differences between the reference condition and expected condition.

Using economic benefit analysis, we identify the changes of, for instance, the cropping pattern, yield, and fertilizer usage, which could be affected by the introduction of surface water in the proposed command area.

Impacts or changes through the introduction of surface water can be measured by estimating the change in the demand and supply functions of the goods and services, resulting from the diversion of surface water, and then measuring the welfare change or change in willingness-to-pay. There are a number of market-based approaches that may be useful in estimating the economic value of changes in the availability of irrigated water. Here, we are adopting a market-based approach in a partial equilibrium framework, to estimate the value of production change in agricultural crops. As the market price of agricultural crops is often distorted by subsidies and the minimum support price, in the given context we will not be considering the change in consumer welfare (consumer surplus).[1]

> Calculation of benefits of surface irrigation requires information about area, yield and cropping pattern both before and after the project. There is a dearth of secondary data on the present agricultural and irrigational scenario of the proposed command area. The sample survey has provided us a lot of information to fulfil the requirement to estimate the benefit of irrigation. The information regarding the Polavaram Project, proposed cropping pattern and potential net irrigated area are taken from the Andhra Pradesh Environmental Impact Assessment Report.

Sampling Plan

A stratified random sampling scheme is used for assessing the direct and indirect economic benefits of irrigation water transfers, as a stratified sample can provide greater precision than a simple random sample of the same size, and thus requires a smaller sample to estimate the true characteristics of the population.

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[1] For such reasons, there is no need to consider the demand side. We can assume that the price of goods is fixed or follows a time trend.

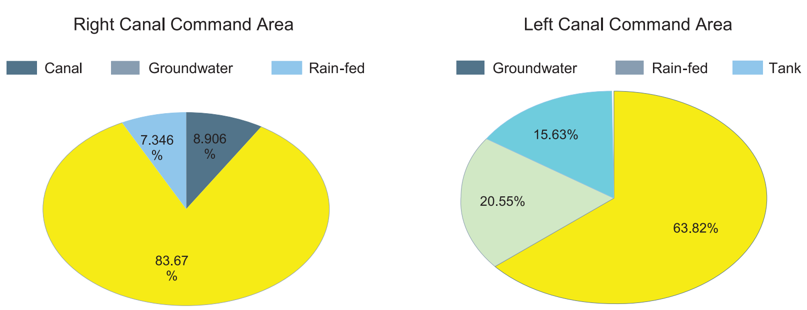
In the stratified random sampling scheme, we first identify the ‘mandals’ in the command area, which could directly benefit from surface irrigation water transfers. Next, we stratify the mandals/villages according to their distance (head, middle and tail) along the canal. Three mandals/villages are selected from each stratum. The water diverted along the canal may supplement areas already irrigated with surface water or groundwater, or may supply new irrigation water to rain-fed areas. Thus we select the three mandal/s villages from each stratum with one each from the surface irrigation, groundwater irrigation and rain-fed agriculture dominated districts.

We have surveyed around 37 mandals and 50 villages. From each selected village, a sample of 20 farmers is selected. Out of 1,000 farmers surveyed, 521 farmers are located in the right command area and the remaining 479 are located in the left command area.

Present Irrigation Conditions of the Proposed Polavaram Command Area

Assessment of the economic benefits of irrigation requires information about the present irrigation area in the command area. The feasibility report of the project prepared by the National Water Development Authority suggests that 70 % of the cultivable command area en route the right bank was already irrigated a decade back. However, our sample survey data indicates that presently only 9 % of the cultivable area in that area remains unirrigated. On the other hand, in the left canal command area, which forms the other part of the Polavaram Project around 66 % of the farm land, is irrigated. In both components of the command area, however, groundwater is the predominant form of irrigation, and accounts for 85 % and 63.82 % of the net cultivated area in the right bank and left canal command areas, respectively (see Figure 2). This also confirms the national trend of groundwater irrigation growth in India. Today, much of the cultivable area in India is irrigated from groundwater resources. In the absence of new large-scale surface irrigation schemes, and the availability of low-cost electric and diesel pumps coupled with little or no electricity charges, groundwater has been a major driver in the expansion of irrigated area.

Figure 2. Irrigated area source-wise in the canal command area.



Source: Based on authors’ estimates

Based on such observations, the premise of our research lies in exploring how the Polavaram command area could benefit from surface irrigation in the case where much of the cultivable area is already irrigated from the groundwater irrigation source.

We hypothesize that the additional source of surface water irrigation can be beneficial but in a limited way, if the farmers in the command area are already using groundwater. After the construction of the Polavaram Dam, surface water can benefit the farmers in the following three ways:

1. After the construction of the Polavaram Dam, farmers who are presently utilizing groundwater may use surface water instead. Lesser dependency on groundwater may help to reduce the agricultural cost.

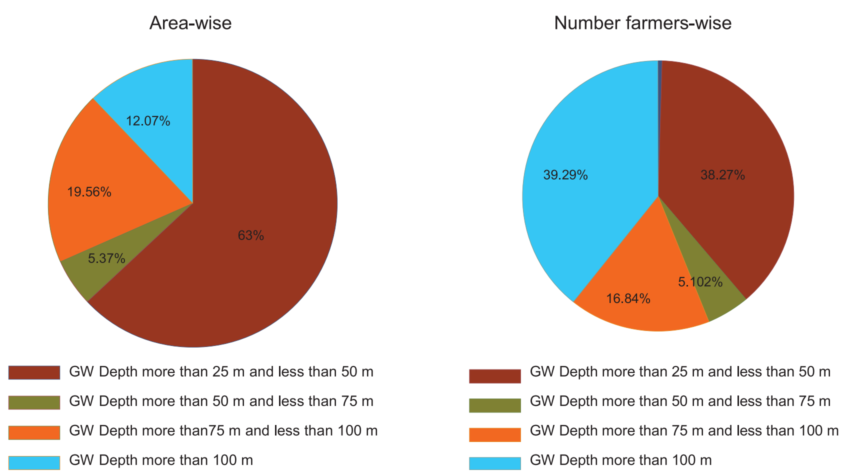
2. Farmers may adopt conjunctive use of groundwater and surface water, which can increase the productivity further.

3. Another potential benefit of a large dam is that seepage from its canals recharges the aquifers, which provide groundwater (Dhawan 1993).

To derive the benefits from surface irrigation, it is imperative to consider the sustainability of groundwater usage. Hence, it is essential to understand a farmer's agricultural behaviour to changes in groundwater conditions.

In the region, groundwater irrigation has been reported to be beneficial in terms of higher productivity and cropping intensity. However, the growing concern is about groundwater overexploitation and falling groundwater tables in the proposed command area. In about 40 % of the samples, the depth of tubewells is more than 50 meters, and in 12 % of the sample it is deeper than 100 meters (see Figure 3). The groundwater situation is worse, particularly in the right bank command area where in 25 % of the samples, the depth of the tubewells is above 100 meters.

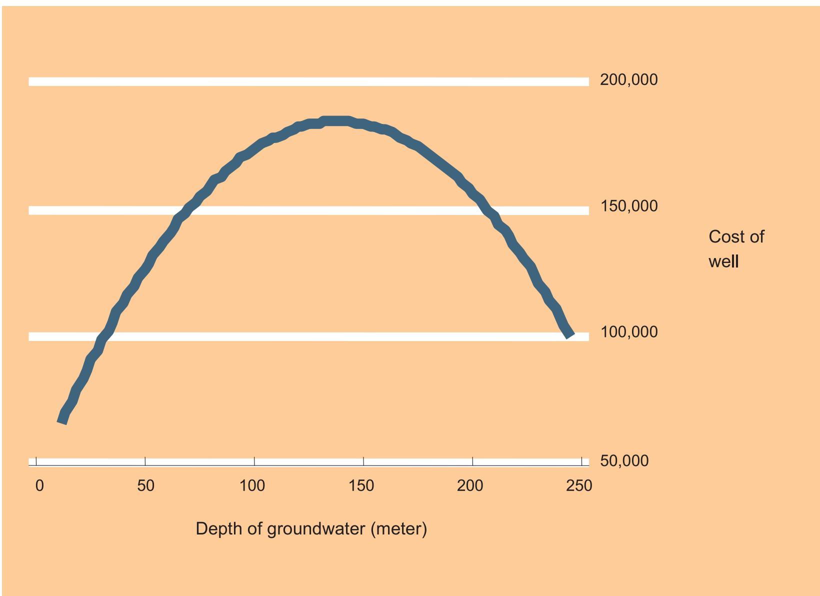
Figure 3. Groundwater depth in the command area: Area and number farmer-wise.



Our analysis suggests that as the depth of groundwater tables increases, farmers invest more in higher capacity pumps, and this is reflected in a concave fitted relationship between the depth of groundwater and cost of tubewells as shown in Figure. 4. Farmers install maximum worth of pumps when the depth of the tubewell is 110 meters. After that the farmers find it economically unfeasible to invest more money in higher capacity pumps for groundwater exploitation, as the marginal cost of groundwater extraction would exceed the marginal benefit.

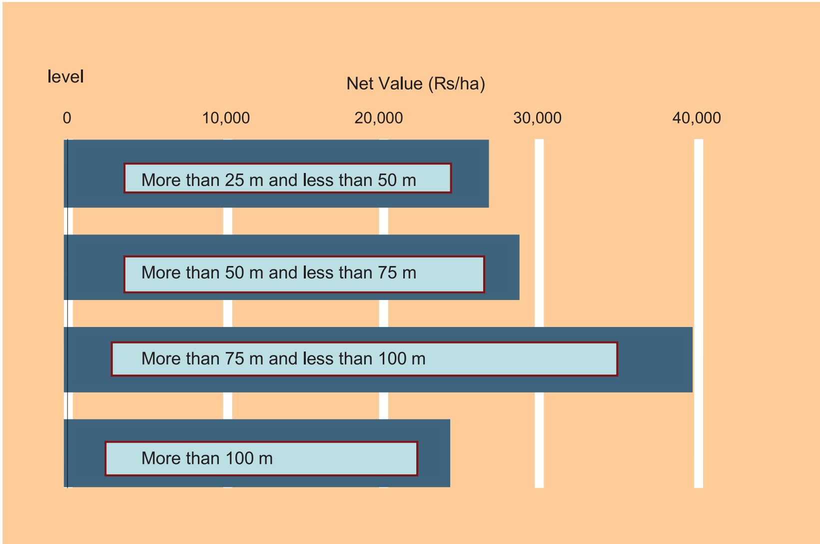
Groundwater depth also could impose constraints in the choice of crops. Our research exhibits that farmers are averse to taking risks and, as such, they prefer to grow multiple crops when there is an increase in the groundwater depth. It suggests that in regions where groundwater depth is less than 25 meters, farmers mainly grow paddy and sugarcane. As groundwater depth increases farmers cultivate different kinds of crops and particularly, cash crops for risk diversification. Then as the depth of groundwater table increases further, the crop choice of the farmers is similar to that of a rain-fed area, where they grow less-valued crops given the limited water availability in such areas.

Figure 4. Fitted relationship between groundwater depth and cost of well.



Net returns from land are also dependent on the groundwater depth. This is evident in Figure 5, which shows the average net value per hectare of land generated at different levels of groundwater. It shows that the average returns per ha of land is high when the groundwater depth lies between 75 and 100 meters and after that the average returns begin to fall. It could imply that as depth of groundwater table rises, farmers employ higher capacity

Figure 5. Average net returns at different levels of groundwater.



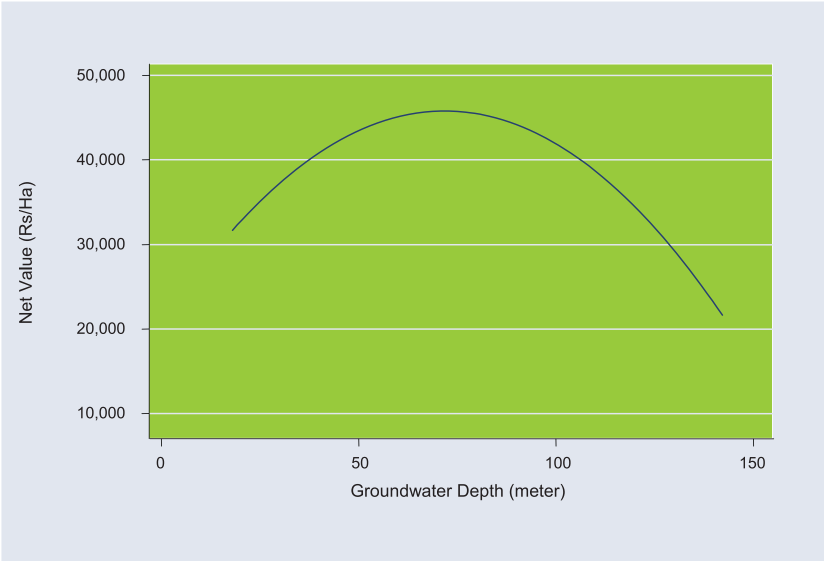
Source: Based on authors' estimates

pumps, and to recover the extra cost they grow cash crops, which allows farmers to get higher average returns.

After this, the opportunity cost of groundwater increases and farmers cannot afford costly pumps and it restricts their income at a lower level. Our analysis also suggests that with increasing groundwater depth, the yield of crops, particularly paddy, decreases. And beyond a certain depth of groundwater, the farmers find the opportunity cost of water to be high. Even though electricity is free, the high cost of groundwater extraction is very much related to the cost of operation and maintenance of the pump including higher horse power used, both of which increase with the depth of groundwater. Figure 6 reveals the fitted relationship between the yield of paddy and groundwater depth. It indicates that the yield of paddy decreases with groundwater depth when the latter is more than 65 meters. Higher groundwater depth represents relative water scarcity and therefore, restricts farmers to use less water and leads to lower crop yield .The relationship highlights the need for a sustainable use of groundwater and to avoid a situation that may constrain the productivity of crops. Hence, surface water could have a bigger role to play in regions where farmers face rising groundwater depth.

As surface water would come in, it could sustain the groundwater usage and allow farmers to get higher productivity with a lower agricultural cost for extracting water. Additional surface water can also help farmers to take more risks to invest in higher capacity pumps and adopt crop diversification in groundwater-irrigated areas, where the average depth is more than 100 meters. Given that nearly 40 % of the farmers are irrigating in areas where the groundwater depth is more than 100 meters, the benefits of the surface water irrigation could be substantial in this region.

Figure 6. Fitted relationship between yield and groundwater depth.



Present Cropping Pattern of the Polavaram Command Area

The benefits of irrigation projects depend very much on the present and future cropping patterns in the command area. From the sample survey we have tried to understand the present cropping pattern in the proposed command area and make a hypothesis of the future cropping pattern of the farmers after the advent of surface irrigation.

In the proposed command area in the right bank, the three main crops are paddy, sugarcane and tobacco. Paddy is grown mainly in the kharif season, while tobacco and sugarcane are the annual crops. In this region, the annual crops are very popular among the farmers. In the right bank command area, annual crops are grown in nearly 65 % of the cropped area, while kharif crops account for only 26 %. Sugarcane and tobacco are the two major crops among the annual crops in the right bank. During the kharif, paddy comprises more than 95 % of the area.

Why is it that the majority of the farmers grow annual crops in the region? Our survey suggests that farmers grow annual crops mainly in the groundwater-irrigated area. It could be argued that groundwater irrigation provides the kind of reliability in water supply that is needed to grow high-valued crops. Also in the case where there is no alternative source of irrigation other than groundwater irrigation, farmers rely on high-valued crops to cover the cost of groundwater extraction, mainly the cost of pumps, operation and maintenance.

In the proposed command area of the left bank, paddy, sugarcane and black gram are the major crops. Here, the dominance of annual crops is much less than in the right bank, and accounts for only 32 % of the cropped area. Sugarcane is the major crop among the annual crops. Much of the cropped area is used to grow one-season crops, and particularly paddy in the kharif.

In the downstream of the Godavari where much of the land is irrigated from the surface irrigation source, the popular crop choice of farmers is paddy. Paddy is grown in more than 90 % of the farm land having access to canal irrigation. With groundwater irrigation, the crop choice is much more diversified like in the rain-fed regions. However, with groundwater irrigation, more high-valued and water-intensive crops are grown than in rain-fed areas.

The key issue that emerges here is how the cropping pattern in the region would change after the introduction of surface water. If the farmers are growing high-valued annual crops by means of groundwater irrigation, would they shift to traditional crops like paddy with the advent of surface water or continue to grow their annual crops with groundwater irrigation? Would the farmers continue to grow-high value annual crops and increase the value of surface water or else like downstream Godavari farmers, grow paddy in both the seasons?

The answer to the issue is also related to the existing cropping pattern trend in Andhra Pradesh, which suggests a paradigm shift in the choice of crops over the past decade. Farmers are shifting from growing traditional crops to high-valued crops. Such a behavioural change in farmers was also reflected in our one-to-one interaction with them. Once the surface water reaches the Polavaram command area, the farmers may show an interest in growing annual crops as before. However, much of this change is due to the demand factor and irrigation conditions. Due to storage constraints the entire area is proposed to be irrigated mainly during the kharif season only (NWDA 1996). Given the limited availability of surface water in the rabi, the farmers may continue to use groundwater in the alternate season. The surface irrigation would help the farmers in sustaining groundwater usage during the rabi season and facilitate the growing of annual crops. The return flow factor as a fraction of surface water usage could be 10-20 %, and this additional water could be used in the rabi season in the form of groundwater irrigation (NIH 199).

Land Use Intensification

Land use intensification is another important criterion for land productivity.[2] Much of the increase in gross cultivated area in the Polavaram proposed command area has been achieved by increasing land use intensification (LUI). We explore here the following: 1) the current land use intensification in the proposed command area and 2) the factors responsible for the increase in land use intensification.

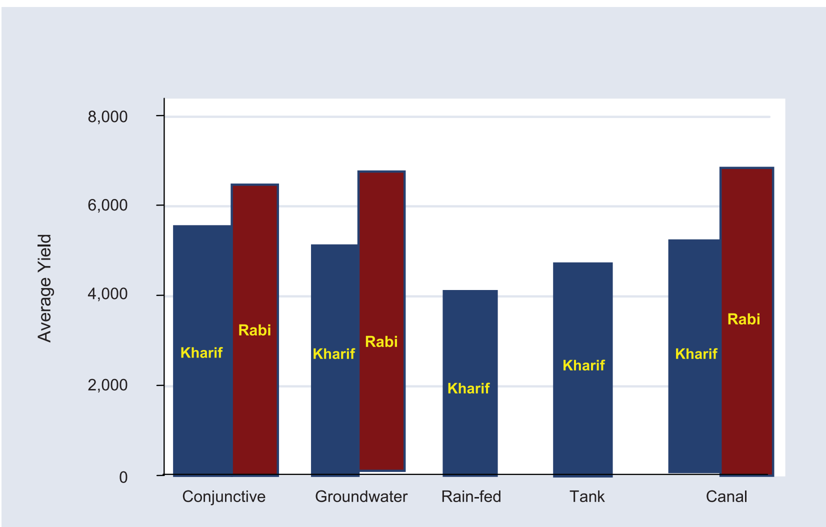
[2] There are many crops like sugarcane, banana, coconut etc., which stand for more than 3 months in the field and computing their land intensity, requires special consideration. Unlike the conventional measure of irrigation intensity, defined as the ratio of gross irrigated area (GIA) to net irrigated area (NIA), (GIA/NIA), we have computed irrigated land use intensity (ILUI) as $\frac{gia + \sum_{j}^{n} nia^{j}}{nia}$ where j is the number of annual and perennial crops, which stands for more than one cropping season in the field.

It is generally believed that surface water irrigation helps farmers to increase the intensity of land use. Our survey results also validate such a widely held hypothesis by citing that the land use intensification is at its maximum in the downstream of the Godavari, where all the cultivated area is irrigated from the surface water source. In addition, as mentioned earlier, much of the proposed command area is already irrigated and, as irrigation is one of the major drivers of the increased intensification of land use, the land use intensifications are 165 % and 110 % in the right and left command areas, respectively. Higher land use intensification in the right bank is due to the extensive cultivation of annual crops using groundwater irrigation. We investigated whether the diversion of surface water in the proposed command area would help the farmers to increase this intensity further. Our analysis suggests that surface irrigation could facilitate farmers to irrigate the rabi crops and increase the intensification of land use. If surface irrigation is limited in the rabi season, then the farmers can alternatively use the groundwater resource. Higher use of groundwater in the rabi season could be possible through surface water recharge or by being less dependent on groundwater during the kharif season.

Yield and Net Returns of Major Crops

The overall objective of a surface irrigation project is to increase the net value of land and support the livelihood of the farmer. However, it is imperative to know whether the increase in net value of cultivable land would be generated from a productivity difference or through a reduction in agricultural cost. We analyzed the difference in yield through the different sources of irrigations. Figure 7 shows the yield of paddy, one of the major crops in the region. The average yield of paddy from conjunctive water use is significantly higher than that of only using either surface or groundwater. Moreover, there is no significant difference in the yield whether the source is groundwater or surface water.

Figure 7. Paddy yields (kg/ha) in kharif and rabi seasons under different sources of water supply.



The average yield of paddy is only 2.43 % higher in farms irrigated from surface irrigation compared to what is obtained in groundwater-irrigated farmland. It implies that from a productivity point of view, we may not expect any substantial difference in the areas that are already irrigated by groundwater, even after the completion of the Polavaram Project. However, if the farmers use conjunctive irrigation, the project could lead to better productivity. The propensity of the farmers to use both groundwater and surface water is higher as the farmers in the groundwater-irrigated areas have already incurred the sunk costs of pumps. The average fixed cost would only decrease if the farmers continue to use groundwater.

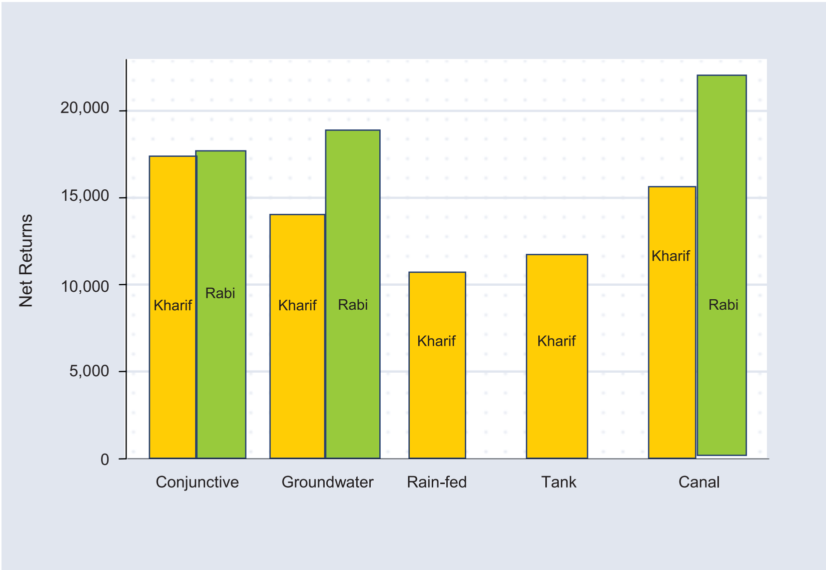
A significant proportion of the land in the proposed command area, particularly in the left canal command area, is rain-fed. Presently the rain-fed yield in the region is 1.6 tonnes per acre, and there is not much variation across the farms. However, the rain-fed yield of paddy is higher than the national average. In these areas, if the farmers grow paddy after the introduction of surface water, our analysis suggests that the productivity difference would become significant.

In the past, much of the irrigated area in the proposed command area was irrigated by ancient tanks. However, today, tank-irrigation has decreased considerably (Palanisami 1991). Tank- irrigation accounts for only 11 % of the left command area. There are several factors, which caused this decline in tank irrigation. In the last couple of decades much of the focus, priority and investment have been shifted to minor irrigation structures and mega projects. Tank- maintenance has also been neglected due to inadequate management resources. Much of the tanks in the area are rain-fed, and for the crops that are grown from tank irrigation, the yield is lower like in the rain-fed area. In the proposed command area, the average yield of tank irrigated paddy is lower than 2 tonnes per acre. So, the tank-irrigated area may also expect an increase in productivity with the proposed water transfers.

We have calculated the net return from cultivating one hectare of land in the region. The return from land is dependent on the choice of crops. As paddy is one of the major and most popular crops, we have compared the net returns of paddy across different sources of irrigation, which is illustrated in Figure 6. Figure 8 shows that net returns per ha of cultivation is high in the surface-irrigated areas in comparison to other sources of irrigation. The difference is higher mainly in the rabi seasons, for instance, net returns in the surface-irrigated area during the latter season is on average Rs. 3,000 higher than in the groundwater-irrigated area. With no significant difference in yield between the two sources of irrigation, the difference in net value can be attributed to the difference in cost due to the higher groundwater extraction cost. In regions where there is a higher depth of groundwater, the difference is even bigger. In the rain-fed area, the net return from paddy is around Rs. 10,000 per hectare compared to Rs. 44,000 per hectare annually in the surface-irrigated areas. An annual increase of Rs. 34,000 per hectare in the rain-fed area is substantial if the farmers grow paddy in both seasons. Since the major proportion of the rain-fed area is located in the left bank of the command area rather than in the right bank, much of the benefits could be reaped in the former part of the proposed command area.

We have also shown that the net value decreases with a higher groundwater depth. The increase in net returns from the groundwater-irrigated areas would be significant, provided surface water irrigation reduces the stress on groundwater irrigation or facilitates groundwater recharge. Though higher recharge helps in reducing the operation and maintenance cost of the pumps, this is still a small proportion of the total cost of groundwater irrigation. Hence, a higher recharge from surface irrigation would increase the net returns from the groundwater irrigated areas in a limited way. However, there is a possibility that a proportion of the current groundwater irrigated

Figure 8. Net returns from paddy production from different sources of water supply.



area could become unsustainable and thereby inappropriate to use, if the farmers continue to exploit the groundwater resource. Without the Polavaram Dam, these areas could well turn into rain-fed areas, as a result of the opportunity cost of groundwater extraction exceeding the economic benefits. The Polavaram Dam, by diverting surface water can create an opportunity for these farmers to rely more on surface irrigation and thereby sustain their agricultural livelihood.

Benefits of Irrigation

Irrigation benefits from the water diversion at the Polavaram Dam is to a certain extent subjective and depends on several factors .Given the ex ante characteristics of the project, the best approach would be to analyse the different plausible scenarios. We attempt to assess the possible irrigation benefit from the water diversion at the Polavaram Dam under four alternative scenarios. We have constructed several scenarios mainly based on the different cropping patterns that the farmers may adopt after the advent of surface water irrigation by the Polavaram Dam.

In the first scenario, we have taken the proposed cropping pattern as suggested by the Andhra Pradesh Environmental Impact Assessment Report (Gujja et al. 2006). A similar cropping pattern is suggested for both the left and the right bank command area. The report suggests that paddy would be grown in the kharif season followed by pulses in the rabi. The report also indicates that the farmers would grow sugarcane and chillies as annual crops.

In the given cropping pattern, although the yield of paddy in the rabi is higher than that of the kharif, pulses have been proposed as a crop choice instead of paddy during the rabi. This could be to reduce the stress on the water demand during the dry season.

In the second scenario given the present popularity of growing maize during the rabi in Andhra Pradesh, we assume that the farmers may grow high-valued maize instead of pulses in the rabi season.

Again, high-valued cash crops like tobacco and sugarcane are grown in the region as annual crops with the help of groundwater irrigation. The farmers have already invested in high sunk cost and they are unlikely to shift completely to surface water irrigation unless the state government imposes a tariff on electricity for groundwater extraction. Under the prevailing circumstances, the farmer may continue to grow these high-valued annual crops even after the completion of the Polavaram Project.

When constructing these scenarios we have also considered the sustainability of groundwater. Our sample survey's results indicate that without the Polavaram Dam it may be difficult for the farmers to continue groundwater extraction in the right canal command area. We have assumed that without the water diversion from the Polavaram Dam, there could be a 25 % reduction in the present groundwater irrigated area. This assumption could be reasonable in that in much of the groundwater-irrigated area of the proposed right canal command area, the depth of the water table is more than 100 meters. The four scenarios constructed are described in Table 1.

Table 1. Scenario description.

Scenario	Description
Scenario-I	Proposed cropping pattern from the Andhra Pradesh Environmental Impact Assessment Report: Paddy-Kharif: Pulses Rabi: Annual crops: Sugarcane and chillies.
Scenario-II	Different cropping pattern - Paddy-Kharif: Maize Rabi: Annual crops: Sugarcane and chillies.
Scenario-III	Present cropping pattern for annual crops
Scenario-IV	25 % reduction in groundwater-irrigated areas in the right canal command area

Table 2. Benefits from irrigation.

	Scenario I	Scenario II	Scenario III	Scenario IV
Annual increase in the value of the crop output (in crores)-Left bank	236.34	276.81	325.60	236.34
Annual increases in the value of crop output (in crores)–Right bank	83.42	141.61	127	146.16
Annual increase in the value of crop output (in crores)– in the total command area	319.76	418.43	452.60	382.50
With multiplier effects (20 %)	383.71	502.11	543.12	459.00
Increase in value (Rs.) per cubic meter of water	0.77	1.00	1.09	0.92

Using the estimated cropping pattern, irrigated area and the net value of crops per ha, we have estimated the total value of the agricultural benefits of crops before and after the completion of the Polavaram Project, for both the right and left command areas. Table 2 shows the possible irrigation benefits from the Polavaram Dam.

The overall annual increase in value of crop per cubic meter of water ranges from Rs. 0.77 to Rs. 1.09 under alternative scenarios. Assuming the cropping pattern proposed by the Andhra Pradesh Environmental Impact Assessment (APEIA) report, the annual increase in the net value of crop output would be 319.76 crores; while taking into account a multiplier effect of 1.20, the overall benefit inclusive of indirect benefits stands at 383.71 crores under the same scenario.

The study indicates that the benefit would be at a maximum of Rs. 1.09 per cubic meter if the farmers continue to grow annual crops, particularly in the right bank canal command area. And the benefit would be at a minimum of Rs. 0.77 per cubic meter of water under the scenario proposed by the Andhra Pradesh Environmental Impact Assessment Report. However, if the farmers grow maize instead of pulses during the rabi season, the benefit will increase to Rs. 1 per cubic meter of water.

The study suggests that the viability of the project depends a lot on the choice of the cropping pattern. If the farmers continue to grow high-valued annual crops with additional surface water, then the benefit would be substantial. As noted earlier, right bank canal command area is part of the river linking project. Since the right bank command area is already irrigated, our analysis suggests that there is insufficient room to increase the economic benefits any further. On the contrary, the annual increase in the value of output could be much higher in the left bank canal command area than in the right bank, where the proportion of rain-fed area is larger. However, benefits for the right command area would increase by 70 % if we assume that the present trend of groundwater growth may not continue and there would instead be a 25 % reduction in the present groundwater irrigated areas.

Livestock Benefits

Livestock is an important source of livelihood in the region. Of the farmers surveyed in the command area, about 66 % possess livestock, which mainly includes cattle and buffalo. Animals are heavily dependent on water largely because of its use for their feed production-an estimated 400 cubic meters or more of water is used per year for the maintenance of livestock. The total water needed may be more than double this amount, with drinking water being less than 2 % of what is required for feed production.We investigated how the livestock population would benefit through the introduction of surface water in the region.

Animal densities are strongly correlated with human densities and are highest in areas of intensified agriculture, especially in and around irrigation systems. In the proposed command area, which is largely irrigated, the proportion of livestock in the region is much less, and one possible reason could be the higher application of tractors and mechanical devices, which reduces the demand for bullocks.

However, an important observation that emerged from our study is that the density of livestock is higher in the rain-fed areas. The number of buffaloes per hectare in the rain-fed area is higher than that in the irrigated areas. In the rain-fed areas, livestock provide a steady source of income for the farmers thereby reducing the variability of income. An important hypothesis is that with the advent of surface irrigation, farmers may invest their effort more in agriculture and retain less livestock.

In our study we have also highlighted another relevant issue, i.e., whether surface irrigation would help increase the milk production of the livestock. Our survey suggests that the milk production of buffalo and cattle are 20 % and 32 % higher, respectively, in the surface irrigated area than in the rain-fed area (see Figure 9). The likely reason for this could be that surface irrigation provides farmers an opportunity to grow fodder as second crop and this generates extra biomass for application to livestock. Hence, with more surface irrigation after the completion of the Polavaram Dam, it could be possible for the farmers to feed their livestock better and increase the latter's milk production. In calculating the net economic returns, we have also analyzed the fodder cost for livestock. The fodder comprises dry fodder, green fodder and concentrates. Concentrates account for more than 50 % of the total fodder cost for both cattle and buffaloes, while green fodder accounts for 40 %. The results indicate that in rain-fed areas with a lower production of fodder, the farmer may have to buy fodder, which can in turn contribute to increasing the marginal cost of milk production.

Figure 9. Milk productivity in areas with different sources of water supply.

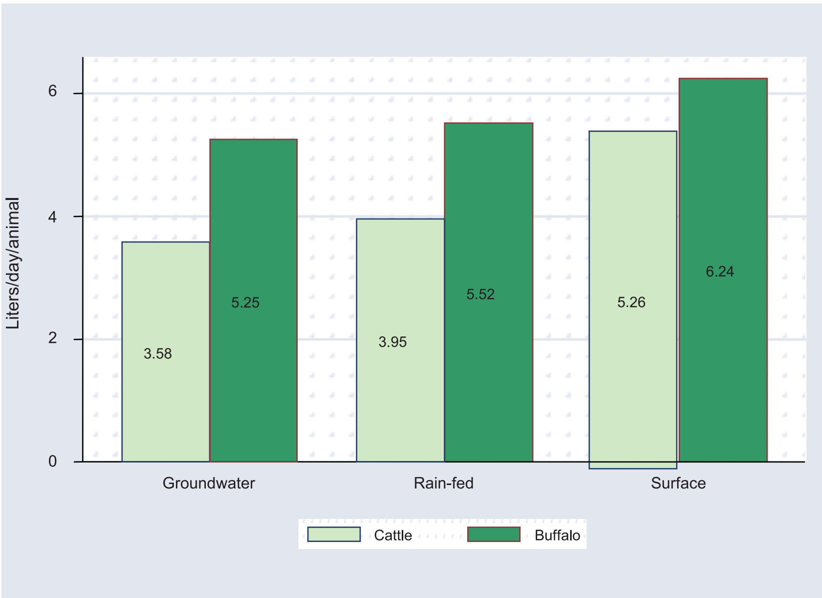


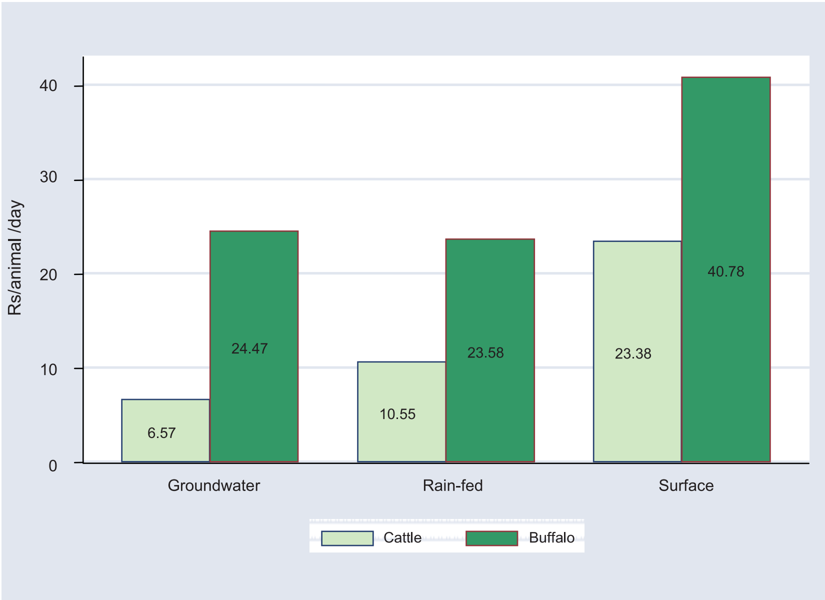
Figure 10 suggests that the net value of milk production (cattle and buffalo) per day in the surface irrigated area is 121 % and 72 % higher for cattle and buffalo, respectively, than that in the rain-fed area. The net gain is Rs. 40.78 per day from a buffalo in a surface irrigated area.

The net value of milk production from a buffalo is also much higher than that of a cow across all sources of irrigation, and that is why farmers prefer to keep buffaloes instead of cattle. In groundwater irrigated areas, for instance, the net value of a buffalo is 72 % higher than that of a cow, but it is only 44 % in the surface irrigated areas.

As the density of livestock is higher in the rain-fed areas, particularly for buffaloes, the net value of a buffalo per hectare in the rain-fed area is similar to that of one in the surface irrigated area, but 23 % higher than that of one in the groundwater irrigated area (Figure 11).

We attempted to assess the livestock benefits from the Polavaram Dam under several alternative scenarios. In our analysis, we found that the number of livestock per hectare is

Figure 10. Net returns per day from milk production in areas with different sources of water supply.



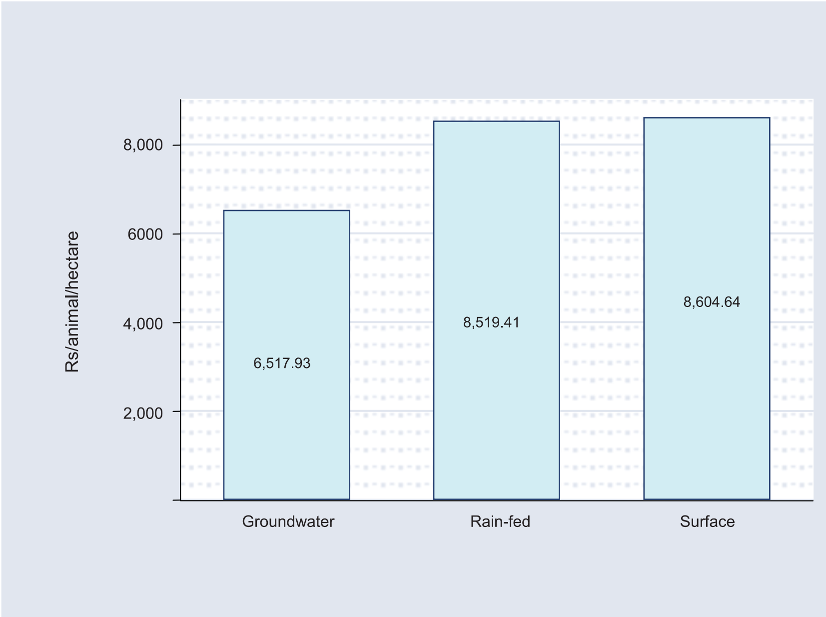
much higher in the rain-fed areas than in the irrigated area, which resulted in a higher net value per hectare. With the advent of surface irrigated water from Polavaram, farmers in the rain-fed area may retain the livestock that is currently providing a continuous income to sustain their livelihood. Farmers may also however, overall retain less livestock with the introduction of canal water and engage themselves more in agricultural activities. In another scenario we have considered a case where there could be a 10 % reduction in fodder cost due to higher fodder production in the irrigated area.

The results are shown in Table 3. It indicates that in scenario I, where farmers could be less interested in retaining livestock after surface irrigation, the net gain would be 10 %. However, if the farmers retain their livestock in scenario II, the gain could rise to 45 % more than at present. In scenario III, the 10 % reduction in fodder cost could result in a yearly gain of 45 crores after the advent of surface water from Polavaram. Livestock can increase the overall benefits of the Polavaram Dam by 8 to 32 %, depending on the different scenarios. The gains would be at their maximum if the farmers grow maize for fodder in the rabi season and retain their livestock.

Table 3. Net gain in milk production benefits after Polavaram water transfers.

Scenario	Scenario	Net Gain	Net Gain (%)
I	Farmers will retain less livestock in surface irrigated area after Polavaram	Rs. 25 Crores	10 %
II	Farmers will retain their livestock in surface irrigated area after Polavaram	Rs. 103 Crores	44.83 %
III	10 % reduction in fodder cost	Rs. 45 Crores	19 %

Figure 11. Per hectare net returns from buffalo milk production in a year.



Conclusion

In this paper we made an attempt to analyze the possible irrigation benefits from surface water augmentation through river linking. The paper illustrates a component of the river linking project of India – the Godavari-Krishna Link at Polavaram. In this proposed link command area, groundwater is the most dominating form of irrigation. This is not in isolation from the national context of India, where groundwater has already been established as the major source of irrigation over the last two decades.

The research paper attempts to address the question – how additional surface irrigation facilities could help farmers to increase agricultural productivity in much of the already irrigated area. In the light of such a premise, our research finds that there is no significant difference in the yield obtained using either groundwater or surface water. Moreover, with electricity usage (which generally forms the major part of the groundwater extraction cost) being subsidized for farmers, there may not be any substantial difference in the agricultural cost .Hence, our study suggests that the irrigational benefits in the command area could be much lower compared to other command areas, as much of the cultivated area in the proposed command area is already irrigated from the groundwater source.

In the region, the growing concern is about groundwater overexploitation and falling groundwater tables in the proposed command area. Results indicate that the yield (paddy) and net returns decrease dramatically as the groundwater depth increases.

Could surface water diversion from the Polavaram Dam be useful in sustaining the groundwater resource where the average depth of groundwater tables is more than 100 meters in 12 % of the proposed command area? The surface irrigation could help the farmers in sustaining water usage during the rabi season and can facilitate the growing of annual crops. The return flow factor as a fraction of surface water usage could be used in the rabi season in the form of groundwater irrigation. Added to this, there will be a lesser dependency on groundwater in the kharif season. Hence, surface water would help in recharging groundwater and reduce the high groundwater extraction cost in the regions, particularly in the region where, at present, the depth of the groundwater table is more than 100 meters. As the depth of the groundwater tables decreases with the help of surface water recharge, it could also help farmers to increase the yield and net value of crops.

Moreover, as the farmers in the groundwater-irrigated areas have already incurred the sunk costs of pumps, they are more likely to use both groundwater and surface water conjunctively. It could bring them further benefits as the average yield of paddy from conjunctive use of groundwater and surface water is much higher than that what is achieved by using either surface or groundwater.

Benefits of a surface irrigation project also depend largely on the crop choice of farmers. Currently there is a popular trend among the farmers to grow high-valued annual crops, mainly in the groundwater irrigated areas. We have demonstrated that higher benefits from the Polavaram Dam could be reaped if the farmers continue to grow annual crops. Such a scenario would have a higher benefit: cost ratio of investments that might be more favorable for the implementation of the project.

Livestock is an important source of income to the livelihood of farmers. The study also attempts to assess the livestock benefits that may be generated from the water diversion at Polavaram. Livestock can increase the overall benefits of the Polavaram Dam by 8 to 32 % depending on the different scenarios. The study shows that livestock benefits will be substantial if the farmers retain their livestock even after the introduction of surface water or with a reduction in fodder cost. The gains will be at their maximum if the farmers grow maize for fodder in the rabi season and retain their livestock.

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