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ARTICLES

WATER MANAGEMENT IN THE MULA COMMAND: A STUDY IN PRODUCTIVITY IMPACT OF CANAL WATERS*

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SCOPE

I have first drawn brief attention to the nature of under-utilisation of surface irrigation potential and then assessed the land productivity on canal irrigated areas, and the resultant increase in output. Both the positive and the negative external diseconomies of canal seepage on crop output are also measured so as to compare the output augmentation effect of improvement in well water-yield in the wake of canal seepage, and the loss of output due to waterlogging because of seepage from canal network. In some sense, this assessment constitutes the main core of the paper, and the reader must bear with both the argument and the fine statistical details. Finally, productivity per unit of canal water is estimated, which is then compared with the corresponding potential level that should have been realised as per the agronomists' research investigations in this area.

THE DATA BASE

The basic data are culled from a detailed techno-economic investigation of the Mula Irrigation Project carried out by the Water and Land Management Institute (WALMI), Aurangabad, and brought out under the title Evaluation Studies of Mula Irrigation Project, Maharashtra in April 1984 (in mimeo. form).[1] Cropwise yield data given in this report were the handiwork of the Gokhale Institute of Politics and Economics, Pune, who were entrusted with the task of socio-economic survey of the Mula command. These data are used by the author to estimate the overall irrigated yield in rice equivalent units[2]—the equivalence scale among the crops is worked out according to the crop prices *recommended* by the Agricultural Prices Commission (APC) in recent years (1980-81 to 1984-85). The author

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* This is a slightly revised version of the draft paper with the same title circulated for comment and criticism in October 1986. Among the scholars who read the draft version, Professor Dalip Swamy, Dr. Kanchan Chopra, Professor S. S. Parihar and Dr. G. Elumalai deserve special mention. I am grateful to them for reading the paper and offering their comments/suggestions.

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1. At the very outset, the author wishes to put on record his gratitude to the WALMI and its staff for doing this painstaking, field-based enquiry. Appreciation, if any, for this short paper must be credited to them also.

2. This scheme of crop aggregation is different from the other scheme adopted by the author elsewhere, in which the segment of food crops are added up in terms of their calorific energy contents and finally expressed in 'foodgrain equivalent' units.

believes that the APC prices aptly reflect the weights which should be attached to different crops in a wider, national perspective. Instead of expressing the overall yield in rupee terms, as is often done in research studies (including WALMI's), rice has been used as a numeraire, because price inflation renders the value in rupees dated in time. Though any crop could have been used as numeraire, rice is preferred, being the single most important crop of the country, notwithstanding its being a crop of marginal importance in the Mula command. The rice equivalence scale used in this paper is as follows:

one kg. of coarse grains	=	0.66 kg. of rice (dehusked paddy)
one kg. of seed cotton	=	2 kg. of rice
one kg. of sugarcane	=	0.1 kg. of rice
one kg. of gram	=	1.25 kg. of rice
one kg. of wheat	=	0.8 kg. of rice
one kg. of groundnut-in-shell	=	1.60 kg. of rice

RESULTS

Under-utilisation of Irrigation Capacity[3]

Mula Irrigation Project has been in operation since 1971-72, when an irrigation capacity for about 20,000 hectares (ha) was created. Estimates of potential created and utilised in recent years are as follows:

Year	Potential created (ha)	Potential utilised (ha)	Percentage utilisation of created potential
1976-77	59,750	33,962	56·8
1977-78	60,730	35,710	58·8
1978-79	65,500	33,430	51·0
1979-80	66,360	28,733	43·3
1980-81	73,320	30,816	42·0
1981-82	73,320	32,104	43·8

While the phenomenon of under-utilisation of irrigation potential is understandable for a project during its construction phase, the high under-utilisation in the case of Mula project is a bit intriguing for a tract with rather low (594 mm.) and highly uncertain rainfall conditions that are typically encountered in the Deccan plateau. The picture of under-utilisation is not that ominous when viewed in terms of volume of water instead of area statistics. Excluding the 'dead' storage capacity of 4,500 million cubic feet (mcft.) in the Dyaneshwar reservoir, the 'surplus' water in the reservoir towards the close of an agricultural year varied as follows:

3. In writing this section. I profited much from perusing Ashok K. Mitra's article ("Under-utilisation Revisited: Surface Irrigation in Drought Prone Areas of Western Maharashtra," *Economic and Political Weekly*, Vol. XXI, No. 17, April 26, 1986, pp. 752-756) which is also based on the Mula Project—the data base is the same, as Mitra, on behalf of the Gokhale Institute, was associated with the WALMI study. I am greatful to him for responding to my queries immediately after the article was published.

Year	Surplus (mcft.)	Date
1976-77	1,713	15th June 1977
1977-78	3,579	21st June 1978
1978-79	487	26th June 1979
1979-80	9,403	1st June 1980
1980-81	1,076	27th June 1981
1981-82	13,189	23rd June 1982

For the six-year period 1976-77 to 1981-82 the surplus reservoir water at the end of an agricultural year amounts to an average level of 4,900 mcft. The average availability of water (as per inflows into the reservoir) during 1976-77 to 1981-82 was around 33,700 mcft. Accordingly, the under-utilisation would work out to 15 per cent only, much below the corresponding average of 51 per cent under-utilisation signalled by area statistics on irrigation potential and utilisation. Even this level of under-utilisation appears to be condonable if one were to duly reckon with the harsh reality of Indian public irrigation works that storage works are usually completed well ahead of the water distribution network. As against the ultimate irrigation potential of the order of 85,000 hectares, the average potential created during 1976-81 was 66,000 hectares, signifying one-fifth of the contemplated canal network to be incomplete.[4]

Thus, from the viewpoint of utilisation of irrigation potential, measured in terms of volume of water instead of irrigable area, the rate of capacity utilisation of the Mula project appears quite normal, that is, nearly full utilisation exists, thereby implying that gross under-utilisation, as indicated by the conventional area approach, does not mean correspondingly high quantum of tapped water being left unused in the reservoir at the end of an agricultural year. What is officially reported to be left in the reservoir can be satisfactorily accounted for by the following factors:

(1) A part of it is 'dead' storage that cannot technically flow into the main canal system.

(2) Some of it is not usable (though it is part of the 'live' storage) for want of an adequate delivery system, as in an on-going project the reservoir capacity for irrigation is much more than the canal network capacity established for delivering water to the farmers' fields.

(3) In some years, inflow into the reservoir is much more than the estimated flow of a given dependability assumed in a project. To illustrate, annual water yield of the Mula catchment ranges between a maximum of about 66,600 mcft. and a minimum of 13,500 mcft., with the 70 per cent dependable yield placed around 29,000 mcft.

4. A part of the Mula Canal command has been submerged by the downstream construction of the Jayakwadi project, necessitating development of new command area under the Pathardi Branch Canal of the Mula Right Bank Canal.

Impact on Crop Yield

Since the inflow into the reservoir is, more or less, let out for irrigation purpose, the interesting question to ask is how much crop output is augmented through the use of such water in farmers' fields. The rainfed yield for four grain crops, namely, jowar, gram, bajra and wheat, average 2.76 quintals (q)/ha in terms of rice equivalents (3.83 q/ha in foodgrain units, *i.e.*, without reckoning with grain prices). With the advent of canal irrigation, crop yields rise substantially, along with the emergence of new crops like sugarcane and summer groundnut that are not growable at all under rainfed farming. Canal irrigated yields for principal crops, based on sample data for 180 farmers, are listed in Table I, both in normal units and in terms of rice equivalents, along with area weights as per the overall crop pattern for canal irrigated area for the Mula command as a whole (and not the observed crop pattern in the sample farms) in the recent years.

TABLE I. CROPWISE YIELDS ON CANAL IRRIGATED AREAS IN THE MULA COMMAND, 1982

Sr. No.	Crop	Area (per cent)	Yield (q/ha)	Yield in rice units (q/ha)
1.	Hybrid jowar (*kharif*)	13·9	15·0	9·90
2.	Hybrid bajra	3·3	15·5 (3·0)	10·23
3.	Paddy	2·6	17·5[a]	11·55
4.	Summer groundnut	11·8	15·3	24·48
5.	Cotton	4·3	10·0[b]	20·00
6.	*Rabi* jowar	23·4	12·0 (4·2)	7·92
7.	Wheat	20·6	16·0 (5·5)	12·80
8.	Gram	2·6	10·0 (3·6)	12·50
9.	Sugarcane	11·8	800[c]	80·00
10.	Foodgrains	66·4		10·28
11.	Non-foodgrains	27·9		47·29
12.	All crops[d]	94·3		21·23

Note:—Bracketted yields refer to unirrigated yields.

a. Unhusked. *b. Kapas* (seed cotton). *c.* Sugarcane. *d.* The survey report also contains yield data for HYV maize (30 q/ha), chillies (10q/ha) and vegetables (150 q/ha). However, their area shares in irrigated crop pattern for the Mula command as a whole are not separately known.

The aggregate crop yield comes to about 21 quintals of rice equivalents per crop hectare actually reported under canal irrigation—it would hardly amount to one ton/ha if adjudged with reference to created irrigation potential. As usual, foodgrains as a group yield far less (about ten quintals in rice units) than non-foodgrains (about 47 quintals), of which sugarcane, the premier crop of the Deccan in the matter of remunerativeness (especially when grown for sale to sugar factories) exhibits a towering yield level of the order of eight tons in rice equivalents. Before assessing the magnitude of output augmentation through each crop hectare area brought under canal irrigation, it may be worthwhile to size up the irrigated crop yields with the corresponding potential levels that appear to be realisable as per the agronomists' expectations based on intensive farming under recommended levels of irrigation. Assuming that experimental yields recorded by the water management experts at the Mahatma Phule Agricultural University (MPKV) at Rahuri (that is well within the Mula command area) are the potential yields for the Mula command as a whole, one finds that the observed aggregate yield during 1982 was about half the potential level of 43 quintals of rice equivalents. (We return to this question of yield gap later in the paper.)

Direct Output Augmentation

The direct output impact of surface irrigation works (canals and tanks) connotes additional crop output on lands that acquire access to surface water flows. A broad reckoning of this additional output is provided by the simple difference between aggregate irrigated and aggregate rainfed yields. Using the more correct procedure $(Y_{IRR} - K.Y_o)$[5]—'K' is a fraction indicating the extent to which irrigated crop pattern is oriented towards crops that need irrigation during the wet season, *viz.*, *kharif* season for most parts of India—, the direct output impact from each of the 30,000 odd hectares irrigated by the Mula project in 1982 amounts to 19.82 quintals of rice equivalents.[6] Since the output impact for each hectare devoted to sugarcane cultivation is extremely high in comparison to all other crops, the magnitude of the overall (direct) output impact of canal irrigation vitally hinges on the relative share of sugarcane in canal irrigated crop pattern. The land productivity of 21.23 q/ha is underpinned with a relative share of sugarcane being one-eighth (as against one-twenty-fifth envisaged by the project planners while reckoning the irrigation potential of the Mula at 85,000 hectares). There are reasons to believe that true share of sugarcane in total canal irrigated area in the Mula command is higher than the reported figure of 11.8 per cent. Farmers do not get easily the authorities' sanction[7] for raising sugarcane on canal water. Raising of sugarcane is restricted to the earmarked few perennial zones of the command subject to the overall restriction that

5. The logical derivation of this formulation is given in the author's other study, titled Studies in Irrigation Impact: Issues of Productivity, Stability and Equity (in press).

6. The value of 'k' parameter used in computation is around 0·51. Summer groundnut in the Mula command is sown rather late and thus spills over to the *kharif*. It is, therefore, counted as a *kharif* crop. With the value of 'K' being half, it matters little for the estimate of output impact if *rabi* instead of *kharif* is deemed the main wet season.

7. In Maharashtra, farmers make formal applications (about a fortnight before the commencement of each of the three crop seasons of a year) to the canal authority for using canal water for a particular crop in the coming season.

sanctioned area under sugarcane would not exceed four per cent of the total potential irrigated area in the whole command. Whereas the sanctioning authority for crops other than sugarcane is usually the section officer (a junior engineer), sanctioning power in the case of sugarcane applicants rests with the Executive Engineer. In connivance with the canal functionaries at the lower level (*e.g.*, the canal inspector who regulates the working of the minors/outlets), farmers grow sugarcane unauthorisedly—such area may be indicated to be under other crops like jowar and maize for which canal tariff is very low in comparison to tariff for sugarcane.[8] Thus, if an hectare under sugarcane is falsely indicated to be under jowar in both *kharif* and *rabi* seasons (that is, one hectare of *kharif* jowar and one hectare of *rabi* jowar are recorded in lieu of one hectare of sugarcane), the overall output impact of canal irrigation gets under-stated by 0.62 quintal (*i.e.*, by about three per cent) for each crop hectare benefitted by canal irrigation as per the official records prepared by the canal functionaries. It is, however, difficult to assess the extent of under-assessment of output impact of canal irrigation on this count.

Indirect Output Augmentation

Critics of Indian canal irrigation have a two-fold reservation about the output-augmenting role of major irrigation works, namely, (1) the step-up in crop yield is well below expectations and (2) a part of the step-up needs to be discounted for the loss of output from waterlogging caused by canal irrigation. Within a decade of its operation, about 6,000 hectares of land in the Mula command is said to have got waterlogged (including land getting salinity). In addition to loss of crop output from this land, one has to reckon with the output lost from land submerged under the Mula reservoir. As against these output losses, one has to take due note of the increase in crop output from groundwater-based agriculture in the command that is otherwise characterised by poor conditions of groundwater availability. In what follows we bring out that the overall external effects on crop activity have been very substantial.

Ever since the introduction of canal irrigation, the seepage of canal water through the unlined canal network—as also field percolation—has substantially added to groundwater availability in the Mula command, thereby giving a fillip to private investment in dug well irrigation. (With the spurt in dug wells in the command, the conniving canal functionaries and unauthorised users of canal water, in the event of a complaint or suspicion by higher canal authority, can get away by taking the standpoint that the real source of irrigation is well water, and not canal water.) This powerful, beneficial external economy of canals on the private rate of return on investment in a dug well has been analysed in detail by this author in his recent book.* Here, I would

8. The irrigation tariff for sugarcane is reported to be Rs. 750/ha as against Rs. 50/ha for jowar and maize, being thus quite conducive to both the conniving parties in the matter of illegal gratifications.

* B. D. Dhawan: Economics of Groundwater Irrigation in Hard Rock Regions with Special Reference to Maharashtra State, Agricole Publishing Academy, New Delhi, 1986.

attempt to take account of the output increase via the rise in area under well irrigation within the Mula command.[9] For this purpose, let us look at the water losses in transit, the main source of improvement in groundwater availability.

The project designers envisaged that almost two-thirds of the water released from the canal headworks, namely, reservoir, would reach the farmers' fields. However, much less water is reaching the farmers' fields. As against 80 per cent conveyance efficiency envisaged for the main canal (from reservoir to distributary heads), WALMI's earlier studies revealed 62 per cent efficiency. Likewise, the assumed conveyance efficiency of 80 per cent from the distributary to the field turned out to be only 35 per cent. Thus, only 22 per cent of the released water reached the fields as per WALMI's early studies.[10] The reasons for the transit losses being excessive are complex. Yet, it needs to be emphasised that unrealistic assumptions in this regard lower the output impact of canal irrigaion to the extent the farmers' irrigation application to crops falls short of the assumed level (which is usually as per the agronomists' recommendations for obtaining good, if not maximum, crop yields).

The available information for the Mula command indicates (*a*) substantial increase in irrigated area per old well existing prior to the advent of canal irrigation in the command, (*b*) substantial change in crop pattern in favour of sugarcane crop under existing wells and (*c*) increase in the number of wells in the command area. These output-enhancing effects can be ascribed to canal seepage. Under natural conditions of groundwater recharge, the gross irrigated area per well would have averaged around 1.4 hectare of which sugarcane would account for nearly 5.6 per cent only.[11] This vital information is based on a survey of 1,320 wells that existed in the Mula command area five years before the commissioning of the Mula project.[12] Assuming that (*i*) crop yields found on canal irrigated tracts during the course of the socio-economic survey of 180 beneficiary farmers, conducted during 1982-83, would have been realised in the case of well water also and (*ii*) the crop pattern observed on wells in the mid-sixties also holds good for 1982-83 without the Mula project, the average crop yield on 1.4 hectare under well irrigation might have been around 16.70 quintals of rice equivalents per crop hectare in the absence of canal seepage of the Mula project.

9. The effect of seepage from canal network can spill over to areas adjoining the command boundary, thereby improving well irrigation even outside the canal command. To illustrate, the old Pravara Canal had substantially improved well water-yield within part of the Mula Left Bank Canal command. This trans-command improvement in groundwater-based farming is not being assessed here.

10. In the project proposal to the World Bank in 1979, the overall conveyance efficiency of the Mula system is proposed to be enhanced from 24 to 38 per cent by way of lining of minors and field channels.

11. This percentage for sugarcane pertains to wells in the command of the Mula Right Bank Canal. In contrast, the percentage for 147 wells in the future command of the Mula Left Bank Canal (MLBC) was 52 because of the high seepage from the adjoining Pravara Canal.

12. The survey data emerged during the course of a pre-project detailed soil mapping of the Mula tract.

The Mula project, in fact, increased the average gross irrigated area per well and induced a sharp change in crop pattern in favour of sugarcane.[13] The study of 255 wells, located within the command of six 'minors' investigated in depth by the WALMI investigators during 1982-83, indicates that the average area per well was 2.6 ha,[14] about 1.2 ha more than the average for the 1,320 wells surveyed in 1966. More importantly, a little over 50 per cent[15] of the benefitted area was used for raising sugarcane. Now, assuming the same estimational procedure as adopted earlier in the case of wells in the absence of canal irrigation (that is, crop yields on canal irrigated areas hold good for the area benefitted by the wells), the aggregate crop yield for wells augmented by canal seepage averages at about 51.31[16] quintals/ha, about thrice the level that would have obtained without the Mula project. The cause of the large hiatus between the aggregate crop yield under wells receiving canal seepage and the aggregate crop yield under wells not benefitting from canal seepage is the radical difference in the crop patterns on the two categories of wells (vide Table II).

TABLE II. COMPARATIVE CROP PATTERNS ON LANDS IRRIGATED BY TWO CATEGORIES OF WELLS

Crop	For wells without benefit of canal seepage	For wells having benefit of canal seepage
Sugarcane	5·6	52·6(52·0)
Wheat	11·0	9·5
Rabi jowar	43·5[a]	19·9
Summer groundnut	—	5·2
Cotton	21·0	—(16·0)
Kharif jowar	—	1·8
Kharif bajra	—	1·6
Other crops	18·9[b]	9·4(32·0)[c]

a. Including *kharif* jowar.

b. 2·5 per cent under fruits, 3·5 per cent under vegetables and 4·4 per cent under lucerne grass.

c. 16 per cent under fruits and 3 per cent under vegetables.

Note:—Figures in brackets are based on 147 wells benefitting from percolation from the Pravara Canal on the border of the MLBC (see footnote 11).

13. This shift in favour of sugarcane is to be partly ascribed to the location policy of the Central Government, whereby Maharashtra State became a highly favoured State in the matter of grant of industrial licences for setting up sugar mills. The establishment of these sugar mills, especially in the co-operative sector, smoothens the change over from less intensive to more intensive farming.

14. As part of the socio-economic survey, 26 wells located in seven villages were found to be irrigating, on the average, about 2·8 ha per well that compares well with 2·6 ha for the 255 wells, despite the fact that four out of the seven surveyed villages were situated outside the Mula command.

15. This percentage is slightly lower for the 26 wells referred to in footnote 14—44·7 as against 52·6 for the 255 wells.

16. If crop pattern, suggested by the data for 26 wells were adopted, the overall yield would amount to 47·79/ q/ha, about 7 per cent below the adopted level of 51·31 q/ha.

As per the records of the Director of Irrigation Research, Pune, the number of wells in the Mula Right Bank Canal command area stood at 5,934 in 1971-72, the year the Mula project was commissioned. Thereafter, the number steadily rose to 8,585 in 1981-82, the annual increment in numbers being of the order of 265 wells. Thus, for the reference year 1982-83 we have to work out the enhanced output based on canal seepage in respect of (*i*) the old 5,934 wells and (*ii*) the 2,916 wells established after the commencement of canal irrigation. For this purpose, we make the following assumptions:

(*a*) Area irrigated per old well rises from 1.4 to 2.6 hectares due to enhanced water-yield in these wells.[17]

(*b*) Overall crop productivity, measured in terms of rice equivalents, is boosted for the old wells from 17 to 50 quintals/ha due to change in crop pattern (in favour of more remunerative crops like sugarcane and summer groundnut) due to water-yield becoming more copious in the wake of canal water seepage, especially during the lean summer season.

(*c*) Each new well established after the advent of canal irrigation irrigates annually 2.6 hectares, each hectare recording a productivity of 50 quintals in terms of rice units.

(*d*) There were 6,000 wells existing in the Mula command at the time of its commissioning, and 3,000 new wells had been established by 1982-83.

Thus, canal waters that seeped through the canal network and the canal irrigated fields helped in the additional production of the order of 0.61 million quintals of rice equivalents during 1982-83 (0.237 million quintals from the old wells and 0.377 million quintals from the new wells). This extra output is a shade less than the estimated output contribution of 0.62 million quaintals from about 31,000 hectares of canal irrigated area (43 per cent of the created potential of 73,000 hectares). In other words, each crop hectare under canal irrigation made a direct output impact of the order of 20 quintals, and an equal indirect output impact through canal seepage used for well irrigation in the Mula command during 1982-83.

If water losses in transit have proved beneficial for well owners, these might have proved deleterious for other farmers in case their lands got water-logged. Statistics of waterlogging and soil salinity, compiled by the Drainage Division of the Mula project, do indicate increase in the incidence of water-logging and soil salinisation within the Mula command—such area rose from 259 hectares in 1970-71 to 7,382 hectares in 1978-79 but declined to 6,604 hectares in 1979-80 and 5,656 hectares in 1980-81.[18] In addition, the danger of waterlogging exists on 23,000 hectares of land in the command, as water table under these lands was found to be between 1.2 m and 3.0 m below the ground surface in 1980-81. Assuming output loss at the rate of 2.76 q/ha from 6,000 hectares of waterlogged land and 5,300 hectares of area

17. These estimates are somewhat on the higher side compared to the corresponding estimates (1·2 and 2.1 hectares respectively) worked out by the author earlier in his book from secondary, taluka-wise data for canal and non-canal-irrigated tracts of Ahmednagar district as a whole.

18. These statistics pertain to areas with groundwater table being within 4 feet (1·2 m) of the surface level, or electrical conductivity of groundwater being above 4·0 mm. ohms/cm.

submerged by the reservoir, the output lost comes to about 32,000 quintals, or to about one quintal per hectare brought under canal irrigation in 1982-83.

It is remarkable that the indirect output impact of the Mula project is a shade less than the direct output impact. (The sum total of the two impacts comes to about 39 quintals for each crop hectare served directly by the Mula reservoir, a level that compares favourably with the potential expected value of 43 quintals as per the water management experts' research work).

I have demonstrated earlier (in my recent book) that incremental output from a well, as a result of enhanced water-yield following the introduction of canal irrigation, boosts up the rate of return on private investment in the well in Ahmednagar district of Maharashtra from a low level of 13 to about 50 per cent. Were we to credit this incremental output from wells existing prior to the commissioning of the Mula project to public investment in this major surface irrigation work, we would discover a corresponding boost up in the benefit-cost (B-C) ratio for this project. The WALMI report indicates a B-C ratio of 0.455 for this project (the ratio could be around 1.83 if the assumptions with regard to crop pattern and irrigation potential were to be fulfilled.) Since the indirect output impact is of the same magnitude as the direct one that has been reckoned with while computing the B-C ratio of 0.455, one may broadly infer that the effective B-C ratio for the project may be twice the computed level. The author has discerned some minor faults in the computations of the WALMI, and if due corrections are made for the same, the correct B-C ratio becomes 0.60 instead of 0.455.[19] Doubling of this corrected B-C ratio—so as to take care of the indirect benefits of the project—gives rise to a value that exceeds unity by 20 per cent.

Productivity Per Unit Volume of Canal Water

As part of its micro level studies, a couple of plots that fell under the command of the six selected 'minors' (that portion of the terminal segment of a canal network from which final outlets take off to the field channels) were chosen purposively by the WALMI investigators who made painstaking efforts to measure the volume of canal water used in irrigation. The number of such plots (54 to be exact) is too small to assess cropwise use of canal water during 1982-83: 15 observed plots were under wheat crop, 12 under groundnut, 9 under sugarcane, 7 each under bajra and *rabi* jowar, and 4 under *kharif* jowar. Cropwise estimates based on such purposively selected plots, especially in respect of crop yields, cannot be considered to be representative of the entire Mula command. On the other hand, we lack cropwise information on volume of water actually used by the 180 sample farmers whose yield data, based as it is on a stratified random sampling design, is otherwise representative for the whole command. Under the circumstances, we first use the

19. The improvement in the B-C ratio is primarily due to our having rectified the WALMI error of computing on-farm income benefits net of the canal charges for various crops paid by the sample beneficiaries. There is no need for such netting if benefits are being compared with costs—yet this is not an uncommon error that unnecesarily biases downwards the B-C ratio for irrigation projects.

54 plot data to get an overall (for all crops together) picture of productivity per hectare-centimetre (ha-cm) of canal water reaching the farmers' fields. This is then compared with the corresponding estimate which is obtained by assuming that one-fourth of the water released from the reservoir reached these farmers' fields.

The relevant data on the sample 54 plots, given in Table III, reveal an aggregate yield of the order of 17 quintals in rice units per hectare. Though this entire yield cannot be attributed to the use of irrigation input of the order of 53 cm/ha, yet it is worthwhile to appraise the use of very scarce resource like irrigation water by relating output to this very input in a production process—the scientists describe this productivity of water as 'water use efficiency.' Since this scarcity of a factor may not be true at an individual farmer level (*e.g.*, a small farmer with a land holding of one hectare would find land more scarce than water), the resultant figure of production per unit of water—which comes to about 33 kg. of rice quivalents per ha-cm of canal water—cannot be used to comment on the farmer's efficiency in resource utilisation. Yet, this ratio is useful from the social perspective in the same way as land productivity in Asian agriculture and labour productivity in Western, industrial economies are meaningful ratios between output and scarce factor of production—land in the Asian case and labour in the industrial case.

TABLE III. CROPWISE YIELD, CANAL WATER USE AND RELATIVE AREA SHARE FOR 54 PLOTS IN THE MULA COMMAND, 1982-83

Sr. No.	Crop	Yield (q/ha)		Canal water (mm.)	Crop area (per cent)
1.	Sugarcane	574	(in terms of cane)	1811	11·8
2.	Summer groundnut	10·23	(nuts-in-shell)	628	11·8
3.	Wheat	15·93		384	20·6
4.	*Rabi* jowar	11·35		216	23·4
5.	*Kharif* jowar..	14·30		175	13·9
6.	*Kharif* bajra	18·36		208	3·3
	Total: (1 to 6)	17·45	(rice units)	529	84·8

Note:—Individual crop means, obtained from plotwise data, are simple arithmetic averages without regard to area under a plot.

The irrigation releases from the reservoir have been well above the planned level, averaging 130 cm, 143 cm and 252 cm per crop hectare under irrigation during *kharif, rabi* and summer seasons respectively—the corresponding planned levels were 45 cm, 60 cm and 97 cm respectively. The water received by the farmers is estimated to be 33 cm during the *kharif* period, 36 cm during the *rabi* period and 63 cm during the summer period. When we reckon transit losses to be 75 per cent, these depths are adequate for carry ing out intensive irrigated farming for most crops except sugarcane. They add up to 132 cm for the whole year as compared to 230 cm recommended for sugarcane crop—recommended applications for wheat, *rabi* jowar, gram, cotton and summer groundnut are 40 cm, 14 cm, 28 cm, 73 cm and 91 cm respectively.

Dividing the recorded volume of water issued from the Mula reservoir by the corresponding area irrigated by this water, one obtains the irrigation delta (at canal head) of 211 cm,[20] of which 25 per cent, that is, about 52 cm probably reached the farmers' fields. Adopting these estimates, the land productivity per hectare of canal irrigated area for the year 1982-83 can be placed at 10.1 kg./ha-cm of canal water released from the reservoir but 40.8 kg./ha-cm of water actually delivered at the farm-gate, a magnitude that is about 8 kg. higher than the earlier estimate of 33 kg./ha-cm—the difference is traceable to crop yield differential in the two sets of data. In terms of output impact analysis, each ha-cm of water issued from the reservoir helped farmers to increase output to the extent of 9.4 kg. from their canal irrigated lands and 9.1 kg. from their dug well irrigated areas, that is to say, about 18.5 kg. in all.

However, from canal irrigated areas they enhanced crop output to the extent of 38.1 kg. for *each ha-cm of canal water reaching them* through the canal network. Interestingly, the Mula farmers' output augmentation of 38.1 kg./ha-cm of canal water reaching them compares favourably with the performance of some other projects serving low rainfall tracts where water is an extremely scarce resource. As per this author's estimational work, the additional output, measured in terms of rice equivalents per ha-cm of canal water, was 37 kg. in Tungabhadra command (Karnataka), 42 kg. in Bhakra Nangal command (Punjab), 26 kg. in Jayakwadi command (Maharashtra) and 22 kg. in Nagarjuna Sagar command (Andhra Pradesh).[21]

20. This estimate is an average for the five-year period 1976-77 to 1980-81, during which about 68,800 ha-metres (10,000 cubic metres = one ha-metre) were annually released, thereby irrigating 32,530 ha (42,800 crop hectares if counted as per the departmental procedure, whereby annuals like sugarcane are counted thrice, and two-seasonals like cotton and chillies counted twice).

21. These estimates are worked out by the author with the help of cropwise data from a recent study, entitled National Cropping Pattern Study in Irrigated Command Areas, prepared by the Operations Research Group, Baroda (July 1986, unpublished). The comparatively lower impact in Jayakwadi and Nagarjuna Sagar commands demands some comment. Whereas Jayakwadi has been commissioned recently, the irrigation deltas for crops assumed in the ORG study are on the high side (presumably these are at canal head, and not at field level). Both the irrigation level and the output impact level for the five projects are as follows:

	Project	Irrigation (mm.)	Output impact per ha* (kg.)
1.	Tungabhadra	762	2,786
2.	Nagarjuna Sagar	956	2,157
3.	Bhakra Nangal (Punjab)	489	2,071
4.	Rajasthan Canal	586	1,930
5.	Jayakwadi	736	1,921

Source: B. D. Dhawan: Production Augmentation through Canal Irrigation: Empirical Results for Ten Major Irrigation Works, Institute of Economic Growth, Delhi, October 1986 (mimeo., for restricted circulation).

* 1984-85 level.

In addition to about 38 kg./ha-cm from canal water entering into the farmers' fields, the water lost in transit (159 cm out of 211 cm released from the reservoir) contributed to additional production on areas served by well water. This output works out to 12.1 kg. (11.5 kg. if output lost on water-logged lands, salinity-affected lands, and lands submerged under the Mula reservoir is taken into account) for each ha-cm of water issued from the reservoir.

The observed water use efficiency of the Mula command farmers using canal irrigation, reckoned at 40.8 kg./ha-cm, is found to be one-third below the potential level of 62.5 kg./ha-cm which is computed from cropwise yield and irrigation data[22] (vide Table IV) generated by the MPKV, Rahuri for optimal

TABLE IV. CROPWISE POTENTIAL VALUES OF WATER USE EFFICIENCY IN THE MULA COMMAND AREA

Crop (variety)	Water use efficiency (kg./ha-cm)	Crop yield (q/ha)	Consumptive use of water (cm)
Sorghum (CSH-5)	130·40	60	46
Sorghum (CSH-8R)	102·50	40	39
Wheat (HD-2189)	90·50	38	42
Bajra (CN-74)	64·00	16	25
Kharif groundnut	54·29	19	35
Summer groundnut (SB XI)	34·29	24	70
Gram (PG-2)	76·67	23	30
Safflower (Bhima)	56·41	22	39
Cotton (Savitri)	42·85	30 (*kapas*)	70
Sunflower (EC 68414)	53·85	14	26
Sugarcane (0-7219)	511·11	1,150 (cane)	225

Note:—Yield and water use efficiency are in original units, that is, not converted into rice equivalents.

farming under good water management conditions. The potential level is not realised, partly because the observed irrigation use (52 cm/ha) was about one-fourth less than the recommended level of 69 cm for all crops taken together and partly because the observed yield level (21.23 q/ha) was half the expected value of 43.32 q/ha. While we cannot say much on the irrigation deficiency at crop level, the cropwise yield deficiency vis-a-vis expected yields is as follows. The yield gap is negligible in respect of bajra, which however is a marginal crop in the canal irrigated tracts. It is in respect of sugarcane that the farmers have been able to come nearest to the expected yield level, with a yield deficiency of 30 per cent as against 70 to 75 per cent for cotton and *kharif* jowar, 57-58 per cent for wheat and gram, and 35 per cent for summer groundnut (overall yield deficiency being 51 per cent). It is not my purpose to dwell on the various factors that are responsible for potential yields being not realised in the field conditions. Yet, one observation may be in

22. Strictly speaking, the experimental data on water use pertains to 'consumptive use' by plants. For low rainfall tracts, this is a good approximation to irrigation requirements, as the field percolation of water below the crop root zone and 'effective' rainfall balance each other in the following identity: consumptive use = irrigation + effective rainfall — field percolation.

order. In a multi-crop enterprise a farmer may validly favour one crop over another in the matter of allocation of scarce resources and his managerial care. It appears that sugarcane crop benefits unduly from such discriminating behaviour of the farmer in the Mula command. Were its cultivation to be curtailed for reasons of spatial maximisation of benefits from public investments, it may give rise to better performance of other crops in the matter of yield deficiency.

SUMMARY AND CONCLUSIONS

As per the conventional area approach, a little under sixty per cent of the irrigation potential of the Mula project appears to be unutilised. Such substantial under-utilisation of irrigation capacity has been observed in many irrigation projects completed since the commencement of the planning era in India in 1951, and it has been a matter of concern and enquiry in both academic and other circles. While the phenomenon of under-utilisation of capacity is to some extent unavoidable in on-going projects, yet two factors have been identified, namely, (1) the observed crop pattern deviating from the contemplated one and (2) in-transit losses of the canal network being much more than the expected levels while working out the project design—the latter factor being primarily pointed out in the writings of the engineers/administrators. In the particular case of the Mula project, the farmers' desire to grow sugarcane that consumes several times the water used by other crops like jowar and wheat has led to an apparent problem of under-utilisation of irrigation potential. Whereas the estimated irrigation potential of 85,000 hectares is underpinned by a four per cent share for this crop, the actual share is thrice this magnitude—in terms of the observed crop pattern the potential capacity is reduced to 44,000 hectares only. To put it briefly, there is no serious problem of under-utilisation of the tapped water. Whatever waters are left unused in the Mula reservoir at the end of the agricultural year are accountable by the fact that the reservoir has been constructed to its full capacity while the water distribution segment is still to be completed—this lagging of the distribution system has been a common phenomenon in several reservoir-based irrigation projects.

With losses in transmission being twice the contemplated level, only about 52 cm out of about 211 cm per hectare released from the Mula head-works reached the farm-gate level. The water reaching the farmer's fields, though about one-fourth less than the needed level as per the water management experts recommendations, boosted dry farm productivity from a little less than three quintals to about 21 quintals/ha in rice equivalents. This step-up in crop yield amounted to an additional crop output to the tune of 2 tons for each hectare brought under the direct benefit of canal irrigation. The losses in transit, notwithstanding the waterlogging caused by them in certain portions of the command, proved extremely beneficial for well owners as the seeped-in waters boosted the well water yield, enabling them to irrigate more area and also bringing substantial proportion of it under sugarcane.

This indirect contribution of the Mula project to output augmentation works out to be of the same order as the direct one. Net of the output lost from waterlogged areas and from areas submerged by the reservoir, the final tally of addition to farm output comes to about 39 quintals for each hectare of crop area officially reported under canal irrigation. This tremendous contribution of canal irrigation should be instructive for critics of canal irrigation —some bitter ones among them (like B. B. Vohra) can be labelled as anti-canal and pro-groundwater protagonists. Once we recognise the vital interdependence between groundwater and surface water, it is easy to realise that a major factor behind the much-eulogised tubewells/dug wells is the seepage from surface irrigation works (canals and tanks), especially in low rainfall areas like the North-West wheat belt and the Deccan plateau. Without conjunctive use of surface and ground waters, exclusive emphasis on the development of one source of water can prove unproductive in the long run.

Given the extreme scarcity of water in relation to land resource in the Mula command that typifies the vast Deccan plateau (hardly one-third of the cropping can be done under irrigated conditions in this region if the limited waters continue to be pre-empted by heavily irrigated crops like sugarcane and paddy), it is instructive to ascertain the output impact per unit of water. This impact comes to about 38 kg. per hectare-centimetre of water received by canal irrigated fields, a level that compares favourably with some other irrigation projects located in low rainfall regions of the country. Yet, there is scope for further improvement in this productivity. This is suggested by looking at the potential level of water use efficiency that can be realised.

The observed water use efficiency of the canal users is about 41 kg./ha-cm (overall irrigated yield of 21 quintals divided by 52 cm). As per the recommended level of crop irrigation, the potential magnitude of water use efficiency comes to about 62 kg./ha-cm (overall potential yield of 43 quintals divided by 69 cm). The gap between the potential and the observed water use efficiencies is partly due to a yield gap (51 per cent) and partly due to irrigation gap (25 per cent). Keeping aside the linkage between the yield gap and the irrigation gap, the yield gap at the crop level is comparatively small for sugarcane crop, which is favoured by the farmers in a multi-crop enterprise in the matter of resource allocation but to the detriment of yields of other crops.