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CONJUNCTIVE USE OF SURFACE & GROUND WATER FOR IRRIGATION WITH SPECIAL REFERENCE TO MAHANADI RESERVOIR PROJECT.

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ABSTRACT

At present, conjunctive use is adopted in commands of Irrigation projects in the River Basin plains where large scale development of Ground Water has taken place during the last few decades. Thousands of shallow tube wells of about 30-35 m depth and with adequate discharge capacity have come up to supplement Surface Water irrigation supplies. This type of use has significantly prevented water logging and soil salinity. In addition to private shallow tube wells, public tube wells are installed by state Government/Public Corporations in area outside canal command to provide irrigation and help small farmers who cannot own individual tube wells. Even augmentation tube wells are constructed along some canals for supply of water in the canal for irrigation during summer.

The paper describes the existing status of the conjunctive use of surface and Ground Water for Irrigation being practiced in India with special reference to the Mahanadi Reservoir Project. The paper also describes the achievements, constraints and suggests the remedial measures for the optimum development of water resources of the country.

1. INTRODUCTION :

Conjunctive use management of multi-source/multi-quality waters can be defined as the management of multiple water resources in a coordinated operation such that the total water yield of the system over a period of time exceeds the sum of water yields of the individual components of the system resulting from uncoordinated operation. The net output in the conjunctive mode is more compared to the net output when each source/ quality of water is used separately. As a result of conjunctive use of surface and ground water resources, it is possible to have optimum utilization of water resources as groundwater could act and function as a balancing storage reservoir and regularization agent.

It will eliminate most of the undesired effects of irrigation like water logging and salinity, helpful in ground water recharge and will be a facilitator of multiple cropping patterns in the command, thus raising the productivity of the irrigated land. Limited attempts have been made to examine its technical suitability in spatial dimension, its economic viability in long term time frame and the management challenges it possesses inherently.

2. CONCEPT OF CONJUNCTIVE USE:

Surface and ground water resources can be conjunctively used either in space or in time. Surface water and ground water resources are considered to have been utilised conjunctively in space when part of the command is irrigated exclusively by surface water and part by ground water. In conjunctive use in time strategy, parts of the command may be irrigated by surface water at one time of the growing period or in one crop season, and by ground water at another time of the growing period or in another crop season. Further supplies from one source can be augmented by those from the other source in order to meet the irrigation demands adequately.

Conjunctive use of the two resources in time can also be considered as one of the alternatives to planning for carry-over especially in drought prone areas where large evaporation from carry over storage reservoirs substantially reduces the effective availability. Ground water resources provide evaporation free carry over and can supplement the surface supplies whenever shortages are experienced.

3. ADVANTAGE OF CONJUNCTIVE USE:

The simultaneous use of surface and ground water has a number of advantages like:

1. It keeps the water table deep enough to avoid danger of water logging or other hazards arising out of shallow water table depth.
2. It provides security against any irregularity in supply of water and ensures crop productivity.
3. Crops of long gestation period can be raised successfully. This is particularity true for Command areas which are supposed to get water for a limited period.
4. Two crops can be raised successfully and even three crops can be taken up in limited areas in a year.

4. ROLE OF SURFACE AND GROUND WATER IN INDIAN AGRICULTURE:

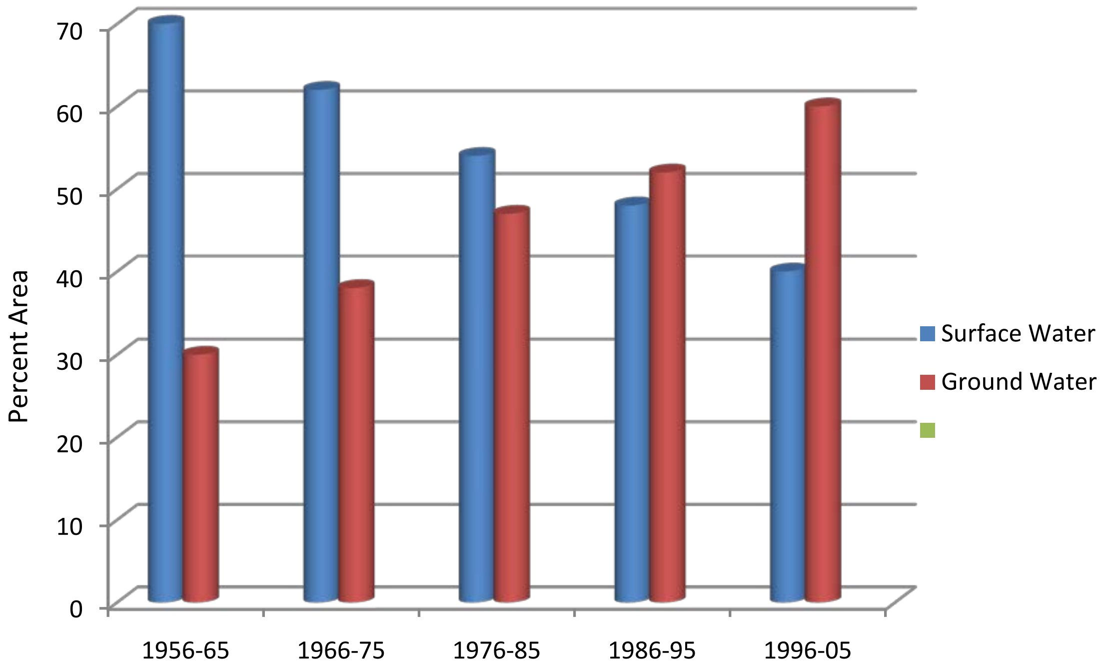
In India, the rapid expansion in the use of surface and ground water, primarily for irrigation, has contributed significantly to its agricultural & economical development. The irrigation potential created from the surface and ground water has increased nearly 8 to 9 times in the last 60 years. In areas of irrigated agriculture, the availability and reliability of surface and ground water sources with high yield variety crops have enabled farmers to increase their income substantially from the agriculture.

As per the data available in the website of directorate of economics & Statistics, Department of Agriculture & Cooperation, Govt. of India (www.dacnet.nic.in), the total food-grain production in India during 2005-06 was of the order of 208.6 million Tonnes. About 90 per cent of the food grain production of the country comes from 13 States viz. Uttar Pradesh (19.4%), Punjab (12.1%) Andhra Pradesh (8.1%), West Bengal (7.5%), Karnataka (6.5%), Madhya Pradesh (6.3%), Haryana (6.2%), Maharashtra (5.8%), Rajasthan (5.5%), Bihar (4.1%), Orissa (3.5%), Gujarat (3.0%) and Tamil Nadu (2.9%). These Sates have about 90 per cent of the total area under food grains and are also major producers of oil seeds and cash crops as well.

Increase in the irrigation facilities from various sources has been one of the major reasons for the increase in net sown area in the country from 118.75 million ha during 1950-51 to 141.36 million ha during 2008-09, registering an increase of about 19 per cent. The gross sown area in the country has increased from 131.89 million ha to 195.10 million ha during the same period, showing an increase of about 48 percent.

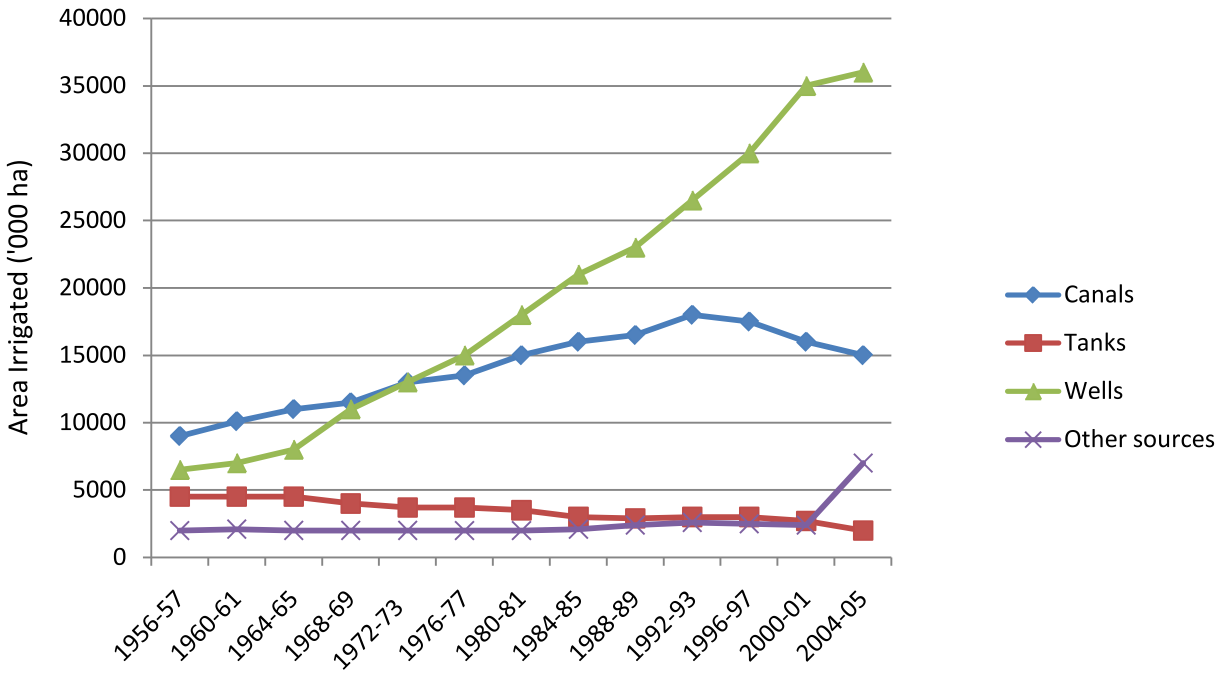
The net area irrigated by different sources in the country has increased from 20.85 million ha during 1950-51 to about 63.20 million ha (provisional) during 2008-09. A comparative study of the percent area irrigated by surface water sources (including Canals, tanks and other sources) and the ground water source (tube well and other wells) (Fig.1) clearly brings out the emergence of surface and ground water as the major source of irrigation in the country in the last 4 decades. The study indicates that the average area irrigated from surface water has decreased from about 70% during 1956-65 to about 40% in 1996-2005, whereas corresponding underground water irrigation has registered an increase from 30% to about 60% during the period. Contribution of various sources of irrigation to the net area irrigated in the country during 1956-2005 is shown in Fig. 2. The data presented in the figure indicates that the surface and ground water have been the major source of irrigation in India since

1950. A steady decline in the area irrigated by tanks, probably due to the destruction of a large number of existing water bodies and their supply channels due to population pressure is another disturbing signal which needs to be looked into more closely by planners and policy makers. Under such situation, the role of Conjunctive Use becomes more relevant.



Decadal Average Area Irrigated by Surface and Ground Water Resources in India 1956-2005

FIGURE 1



Area Irrigated by various sources in India (1955-2006)

FIGURE 2

5. STATUS OF CONJUNCTIVE USE OF SURFACE AND GROUND WATER IN INDIA- AN OVERVIEW:

None of the states, so far have formulated clear cut operational plan for Conjunctive use in any irrigation project though bulk of attempts through research and extension agencies have been undertaken. Reviews indicate no irrigation project has either been planned or designed and operated on conjunctive use principles so far, which can incorporate the institutional frame work, socio-economic factors of wide range of stake holders and policy guidelines for development of water resources along with the technical aspect of canal management.

The consequences of ignoring the concept of conjunctive utilisation have of late, manifested as water logging, salinity, alkalinity, etc thereby affecting agricultural productivity and causing environmental hazard.

In this connection, Central Ground Water Board (CGWB) has carried out studies of 13 completed irrigation projects experiencing in one way or other reduced yields of food crops, due to the problems of water logging, salinity etc. with the following objectives.

(i) To evolve a suitable plan for controlling the problem of rising water levels by adopting the technique of conjunctive use of surface and ground water, and proper drainage.

(ii) To prepare sector/ block-wise plans for development of ground water resource in conjunctive with surface water based on mathematical model results.

(iii) To test the sustainability of the present irrigation pattern with respect to conjunctive use of water resources and suggest improvement for future.

(iv) To evaluate the economic aspect of ground water development plan with respect to Cost benefits ratio, internal rate of return and pay- back period, etc.

The gist of the findings of such studies in respect of some of the projects is given below:

(i) Indira Gandhi Nahar Pariyojana, Rajasthan

The Project envisages 649 km long canal taking off from Harike Barrage downstream of the confluence of rivers Beas and Sutlej. It provides annual irrigation of 9.72 lakh ha in the districts of Churu, Sriganganagar, Jodhpur, Hanumangarh, Bikaner and Jaisalmer of Rajasthan**.**

During 1992, a detailed study on water logging was carried out and it was found that an area of 2.39 lakh ha was affected by water logging in one way or the other. Further, an area of 1.73 lakh was affected by the problem of salinity. Seepage into the soil was attributed as the main reason of the problem of water logging. As a solution, it was suggested that cropping intensity be raised to 110% along with increasing the ground water development of 18% of the canal release. Accordingly, under the conjunctive use plan, 10,023 shallow tube wells were suggested to get an optimal cropping intensity of 120%. The cost of investment for the construction of these shallow tube wells was estimated to be Rs. 721 million with the benefit cost ratio of 1.03.

(ii) Sarda Sahayak Irrigation Project (SSIP), Uttar Pradesh (UP) :

SSIP is an old irrigation project of UP with CCA of 1.923 million ha with 96% irrigation intensity. In course of time an area of 0.49 million ha was found to be waterlogged in 1992 and that of 0.025 million ha of land affected by salinity. This made the tail end of the canal command deficient in surface water availability leading to reduction in paddy (HYV) yield by 38.75% in Kharif season and wheat yield by 84% in Rabi season. Under the conjunctive use plan, it was proposed to reduce the surface water utilisation from the present 1482 MCM to 1016 MCM with simultaneous increase of ground water utilisation from 906 MCM to 1356 MCM. Accordingly, 21375 tube-wells were suggested at appropriate interval in the command. The estimated cost for constructing the wells was estimated to be Rs. 931million. With this change, the existing cropping intensity is expected to be increased from 153% to 200%. The benefit cost Ratio computed to be 1.56 for the proposed plan.

(iii) Tungabhadra Canal command Area, Andhra Pradesh and Karnataka:

The project envisages a dam across the river Tungabhadra along with a 227 km long Left Bank Canal which irrigates 2,43,900 ha; 251km long Right Bank Canal which irrigates 37,503ha, a 15 km long Left Bank High level Canal which irrigates 469 ha and a 110 km long Right Bank High Level Canal which irrigates 80,908 ha of Karnataka and Andhra Pradesh

During the course of operation, many parts of the command got affected with the problem of salinity and alkalinity. According to one study in 1984-85, 35,000 ha (20,870 ha in right bank canal command and 14,230 ha in left bank canal command) was affected by salinity while another study in 1990 indicated that 1300 ha and 6700 ha were suffering from water logging and salinity problems in left and right bank canal command respectively. Conjunctive use study indicated two possible development plans for warding off salinity and water logging problems. By implementing integrating ground water development by these two plans, 86% of the canal water deficient area could be irrigated and the remaining 14% of the water shortage areas could be brought under irrigation by adopting water saving methods. By doing so, the cropping intensity would be increased from 62% to 116%. The financial analysis showed that underground water development plan with annual investment of Rs.2350 million, the benefit would be much more giving rise to B.C.Ratio up to 3.45 and IRR up to 48 %.

(iv) Ghataprabha Canal Command Area, Karnataka

The Ghataprabha Project comprises a reservoir across the River Ghataprabha near Hidkal in Hukkeri Taluk of Belgaum district in Karnataka, a Left Bank Canal from the existing Dhupdal weir (downstream of the dam) at Hidkal and Right Bank Canal from the Dam. The project was designed to provide annual irrigation to 3, 17,447 ha.

During the operation of the canal in the first 6 years after its completion, it was observed that command experienced a general rise in water table by 2 metre, thus causing the water logging problem. To ward off the water logging problems, a conjunctive use plan was suggested by way of constructing 8,880 bore wells in the left bank canal command and 11,739 bore wells in the right bank canal command. By doing so, the cropping intensity in the left bank increased from 84% to 200% with the utilization of 84% of surface water and 16% of ground water. Similarly, in the right bank canal command, the cropping intensity enhanced to 140% with the utilization of 69% surface water and 31% ground water. Such conjunctive use plan indicated an investment of Rs. 406 million with B.C.Ratio varying from 1.25 to 5.34.

(v) Hirakud Canal Command Area, Odisha

Hirakud dam, built across Mahanadi river about 14 km upstream of Sambalpur town in Odisha state, is a multi-purpose project with CCA of 1,57,018 ha and 170% irrigation intensity. The project was completed during the sixties. Years after its construction, the command started experiencing water logging problems in an area of 17,400 ha during pre-monsoon (May1994) and that of 149,400 ha during post monsoon period (Nov.94).

Various conjunctive use strategies consistent with different demand scenarios were tested with the ground water simulation model. Consequently, it was observed that with the utilisation of 90% surface water and 10% ground water in conjunctive mode, the water logging could be minimized substantially at an estimated cost of Rs. 954 million with B.C. ratio of 1.66 and the internal rate of return (IRR) of 55%.

In the study of the remaining projects also, specific suggestions were given to minimize the water logging problem with the help of conjunctive use of surface and ground water which also proved to be cost effective thereby increasing the food productivity..

Overall, with such studies, it was observed that conjunctive use of surface and ground water was found to be best suited plan for the enhancement of the food production and eradication of perennial problems arise due to surface irrigation.

6. NATIONAL WATER POLICY IN RESPECT OF CONJUNCTIVE USE:

National water policy 2002 emphasises the need of conjunctive use in an Irrigation Project and states that, “Integrated and coordinated development of surface water and ground water resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation.”

7. ROLE OF CWC FOR ENSURING THE CONJUNCTIVE USE:

Water Resources development has always remained the priority area for India in view of its importance in achieving food security, drinking water supply, industrial development, hydropower generation, etc.
CWC has been playing key role in the development of water resources in the country in various capacities since its inception despite the fact that the water is a State subject under which State may plan, formulate, design and execute a water resources project depending upon its priority.

Appraisal of Irrigation proposals planned and formulated by the State Government is one of the important activities of CWC. As per the existing requirement of investment clearance of a major (CCA more than 10,000 ha.) as well as a medium (CCA in between 2000 ha to 10,000 ha.) irrigation project, state government is required to submit project proposal to CWC for techno-economic appraisal and ascertaining its technical feasibility and economic viability. During the appraisal, the surface and ground water availabilities are assessed by CWC and CGWB respectively. The project proposal is accordingly optimized and finalised by CWC based on the irrigation requirement and water availability from both the sources so as to make use of surface and ground water judiciously.

During 2010-11, following project proposals have been techno-economically examined by CWC wherein conjunctive use of surface and ground water has been proposed in order to ensure optimum water and food productivity.

(i) Indira Sagar (Polavaram) Project, A.P.

Indira Sagar Polavaram Multipurpose Project envisages utilization of 12735.97 MCM (449.78 TMC) of water by constructing a dam across the Godavari river in West Godavari district of A.P. in the upstream of Godavari Delta to provide annual irrigation in 4.36 lakh ha in the command of 2.91 lakh ha (culturable). The project contemplates the utilization of 4669.31 MCM (164.90 TMC) for irrigation purpose including 1300 MCM (45.92 TMC) of ground water .The project is presently under execution. Under the project proposal, there is provision of utilisation of surface water as well as ground water in conjunctive mode. CGWB estimated the ground water balance of 74.91 TMC (post project conditions) in the command after considering the existing availability and draft. After creation of the proposed irrigation facilities in the area, it was suggested by CGWB that suitable plans may have to be implemented for developing ground water to an extent of 52.44 TMC. Polavaram is basically irrigation project meant for utilising surface water with help of the dam on Godavari. However, there was shortage of 62.33 TMC of surface water which was to be supplemented by ground water resources. 62.33 TMC surface was converted to net irrigation requirement of 34.43 TMC considering the overall efficiency as 55.25%. Considering overall efficiency of ground water utilisation as 75%, the equivalent ground water requirement was 45.92 TMC which is less than the quantity available i.e. 52.44 TMC. The Government of Andhra Pradesh has agreed to install sufficient number of dug wells/ tube wells in the command at appropriate places.

(ii) J. Choka Rao Godavari Lift IrrigationScheme, A.P.

The project contemplates an intake structure at the right bank of river Godavari near Devadula in Warangal district and water conductor system consisting of pressure cum gravity channels including integration of existing tanks along the water conductor system. Besides, it also contains additional new balancing tanks. The project envisages lifting of 1081 MCM (38.16 TMC) of water directly from the Godavari river in Warangal district of A.P, to provide an annual irrigation of 2.86 lakh ha in the command of 2.49 lakh ha (culturable). During the appraisal it has been found that the surface water availability did not meet the irrigation water requirement as the water in the river would be available generally during the monsoon, whereas the requirement would remain beyond this period. Thus, in order to meet the irrigation requirement during Rabi (i.e. from December to May), about 353 MCM (12.47 TMC) of tank yield and ground water in the form of balancing storage in or around the command was considered to supplement the surface water irrigation. The Project Authorities planned to install sufficient number of dug wells and tube wells in the command at appropriate places.

(iii) Urmodi Irrigation Project, Maharashtra:

Urmodi Irrigation project, Maharashtra consists of an earthen dam across Urmodi River, a right bank tributary of Krishna River in Satara district of Maharashtra. The project contemplated to provide Annual Irrigation to 43873 ha in the command (culturable) of 37,000 ha in Satara district.

The overall crop water requirements for the project was assessed 291.506 million cubic metre out of which 252.249 MCM was proposed to be met from surface water. The remaining requirement of 39.257 MCM was proposed to be met from the ground water during Rabi season (Nov. to March) so as to make the project successful. Accordingly, the possibility of ground water was explored by CGWB and it was found that ground water available for irrigation in post implementation condition would be 20 MCM in Satara Taluka, 30 MCM in Khatav Taluka and 34 MCM in Man Taluka. The project authorities planned for installation of 1000 tube wells in the command.

(iv) Irrigation System in Haryana:

Irrigation requirement of Haryana State are met mainly through western Yamuna canal system and Bhakra Canal system. The Yamuna water allocated to Haryana are basically utilised in southern parts of Haryana through western Yamuna Canal system and lift canal system. The Haryana also receives its water share of Bhakra Dam through Bhakra canal system which is utilised for irrigation basically in the northern and western parts of Haryana. The two main system viz. Bhakra Canal System and Western Yamuna Canal System are connected through the Narwana Branch Canal Link. The supplies are transferable from one system to another. The areas which are not covered by the aforesaid two sources are being covered by a lift scheme.

In order to meet the deficit irrigation requirement during the lean period, State Government made provision of approximately 15 kms long augmentation canal which was constructed almost parallel to lower reaches of Western Yamuna Main Canal. This augmentation canal is linked to the main Canal at RD 68,036 and RD 1,16,000 . The capacity of the augmentation canal is 4500 cusecs. A number of public tube-wells are installed along the augmentation canal so that during the monsoon, the flood water percolates to the ground thus raising the water table in the area which can be pumped into the augmentation canal. The water thus discharged into the augmentation canal ultimately supply the water to the main canal for meeting the irrigation requirement in the area during the lean season. This sets a unique example of the conjunctive use of surface water from two different sources and ground water as well.

(v) Mahanadi Reservoir Project, Chhattisgarh

The Mahanadi Reservoir Project comprises Moorumsilli Dam, Dudhawa Dam, Ravishankar Dam and New Rudri Barrage along with 116 Km long Mahanadi Main Canal and 42 Km long Feeder Canal feeding water to Tandula canal and its distribution network. The Project is providing at present an annual irrigation to an area of 2, 64,000 ha.. Besides, it supplies 75 MCM water to Bhilai Steel Plant and drinking water to Raipur and Dhamtari Towns.

It is worth to mention here that this is one of the oldest irrigation systems of Chhattisgarh state which was initially commissioned in 1915 for meeting the irrigation requirement to nearly 2700 ha with the construction of merely one weir. With the passage of time, the annual irrigation rose to 2.64 lakh ha which was provided irrigation with the construction of 3 additional reservoirs in three stages.
During the techno-economic appraisal of the project in CWC, it was observed that the surface water available was insufficient to meet the demand for irrigation in the command after meeting the demands of drinking water to the en-route towns and industrial requirement to Bhilai Steel Plant.

In view of the facts stated above, assessment of ground water potential was undertaken by CGWB. It was found that there was net availability of 365 million m^3 of ground water in the command. Table -1 explains ground water potential for the culturable command area proposed in Mahanadi Reservoir Project. Table-2 explains source wise availability of water and demand. It can be seen that there is availability of 1192.59 MCM of surface water for irrigation against water requirement of 1514 MCM. Therefore, groundwater was utilized in conjunction with the surface water in order to meet the deficit demand in the command as per Table-3.

Table-1

Proposed Monthly Use of Ground Water

Month	Ground Water Potential (Mm^3)
June	57
July	97
August	98
September	98
October	Nil
Total	**350**

Table-2

Source Wise Availability of Water And Demand

Water Availability	
Surface	1192.59 MCM
Ground Water	350.00 MCM
Total	**1542.59 MCM**
Water Requirement	
Irrigation	1262 MCM
Domestic	61 MCM
Industrial	75 MCM
Evaporation Loss	116 MCM
Total	**1514 MCM**

Table-3

S.N	Canal Command	Cultural Command area (Proposed) (in ha)	Gross recharge		Utilisable recharge		Net Draft		Ground Water Balance	
			Rate (m/ha)	Volume (Mm^3)	Rate (m/ha)	Volume (Mm^3)	Rate (m/ha)	Volume (Mm^3)	Rate (m/ha)	Vol. (Mm^3)
1	**Mahanadi Main Canal**	963.77	.272	262	.162	156	.015	15	.147	141
2	**Mandhar Branch Canal**	437.34	.269	117	.161	70	.018	8	.143	62
3	**Abhanpur Lift Canal**	132.80	.265	35	.158	21	.013	2	.145	19
4	**Lawan Branch Canal**	538.66	.282	150	.168	90	.011	6	.157	84
5	**Baloda Bazar Branch Canal**	245.06	.266	65	.158	38	.011	3	.147	35
6	**Bhatapara Branch Canal**	175.70	.258	45	.154	28	.018	4	.136	24
7	**Mahanadi Feeder Canal**	148.10	.							
	Total	2641.43	674		403		38		365	

It was suggested by CGWB that conjunctive use of ground water can be made by installing ground water structures in the command to provide irrigation using ground water to cover the area below canal outlets to meet the requirement of water for raising nurseries of early varieties and supplement the surface irrigation especially during Kharif season and during Rabi season, if required and available. In the project planning 3,333 tube-wells was considered to be provided at state government expenses which would be transferred to farmers under Participatory Irrigation Management Program.

8. CONSTRAINTS IN ADOPTION OF CONJUCTIVE WATER USE:

Translation of conjunctive approach to reality is not as simple as it appears. Conceptually it possesses many challenges. Few of them at macro and micro levels are listed below:

Macro Level

- Conjunctive use of groundwater and surface water often occurs by default. There is lack of big opportunities to enhance its gain in the introduction of planned conjunctive management through coordinated strategies at various levels.
- There is absence of planned investments required in hardware (system modernization and improved infrastructure), software (improved database), planning and management capacities, and institutional reform which is essential to achieve effective conjunctive management.
- Main system management which is central to better conjunctive management that needs to be improved. Water level control is critical for better main system management which needs to be made effective through intervention at appropriate level from time to time.
- There is lack of R & D support in ensuring the conjunctive management in a poor water quality environment as it presents more difficulties, and often requires unique technical and management challenges which in turn seeks higher investment.
- There is lack of strong incentives for conjunctive management among different stakeholder groups. Typically, perverse incentives through faulty pricing of surface irrigation, electricity for pumping, and investment in groundwater structures undermine gains from conjunctive water management.
- Lack of land consolidation.

Micro Level

- High initial investment which a small and marginal farmer cannot afford.
- High recurring expenditure due to costly fuels and lubricants.
- Frequent power failure.
- Lack of awareness among the farmers about the selection of pumps, motors etc. as per the individual requirement.
- Lack of trained manpower for efficient operation and timely maintenance of the pump, motors and other appurtenances.

9 REMEDIAL MEASURES

In order to make the conjunctive use more practicable, some of the measures for utilizing both the resources optimally are proposed as hereunder:

(a) Prioritisation :

As per national water policy, drinking water has been accorded the top priority followed by irrigation and industrial use. Ground water is a precious treasure bestowed by nature. It can be utilised to the fullest extent for domestic purpose. For irrigation purpose, surface flow should be fully utilised first and the balance requirement, if any may be met by ground water resources. In case of industrial use, medium and small industries should be encouraged to utilised ground water.

(b) **Wasteland Management :**
Nearly 11 % of the geographical area of India is assessed as waste lands. These lands have been left uncared for many years. Available ground water is sufficient to grow crops like pulses, cereals, trees of economic importance and horticultural crops. Ground water utilisation should be coupled with proper water harvesting measures like micro-catchment, v-ditch technology, water spreading, contour trenching, catch pit farm ponds and percolation ponds.

(c) **Recharging:**
The overall ground water exploitation scenario in India is highly uneven and shows considerable variations from place to place. Some of the areas in North-western and southern states are reported to be exploited to a higher extent making them either over exploited or critical. These areas should be recharged by adopting suitable techniques like flooding, artificial recharge etc.

(d) **Monitoring and evaluation:**
There must be a monitoring and evaluation mechanism to check the effectiveness of conjunctive use system regularly. Development of a good Management Information System (MIS) is desirable in this connection. For the effective monitoring, systematic ground water observation on a continuous basis is necessary for sustaining the conjunctive use in the command on a long term basis.

(e) If not required, the irrigation channels should be left unlined so that these can be transformed into recharge system at minimum cost. In addition to providing conveyance of the water for canal irrigation, unlined earthen channels serve as recharging system and increase the percentage of water percolating into the ground, thus refilling the underlying aquifers. This water can be subsequently withdrawn during the lean season to augment the canal water supply or in the post monsoon season for a second crop thus, enabling multiple cropping and benefiting farmers at the tail end of the command area. The resulting drawdown of the aquifers maximizes the storage potential for the second monsoon and hence prevents water-logging and salinity.

(f) The power requirement from the non-conventional energy sources like solar, wind energy etc. should be explored and made available to the individual farmer to the maximum possible extent.

(g) Development of a decision support system on conjunctive water practice and their absorption amongst the stake holders.

10 RECOMMENDATIONS

- Even where river basin institutions are absent or underdeveloped, planning of conjunctive management needs to be best done within a river framework.
- The biggest new opportunities for improving food security and livelihoods arise in densely populated agricultural regions that rely on intensive use of ground water in agriculture. In such cases, conjunctive management requires a paradigm shift. The need and pressures are for augmenting and concentrating ground water recharge through recharge structures to increase percolation from rainfall and runoff.

- Conjunctive management investments should strike a balance between improving infrastructure and building conjunctive management capacities-through improved monitoring systems, institutional reform, improved management practices, and greater incentive compatibility.
- Census of the conjunctive use practices taken up by the individual in different projects should be done compulsorily so that the lessons learnt from such ventures by the individuals may be compiled and documented. Based upon these documents, the proper planning on the conjunctive use practice may be drawn on state/ central government level.
- In order to make the conjunctive use practice more popular and sustainable, the irrigation project and its command area development works should be compulsorily taken up pari-passu and accordingly their financing, if required, should be clubbed.

CONCLUSION

To optimize conjunctive use of surface and ground water, the best way is to improve the capacity building of state and central irrigation/ water resources departments in order to improve system management and reshape hydraulic infrastructure of large and small surface systems. To sustain ground water use in tube well irrigated areas, enhancing recharge from precipitation and surface water imports is necessary. None of these improvements can be made without the proper institutional and organizational developments leading to participatory water use association and integrated water resources management.

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