A REVIEW | International Journal of Agricultural Engineering | Volume 13 | Issue 1 | April, 2020 | 137-144
ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/13.1/137-144**

Conjuntive use planning of surface and ground water resources

K. Kishan and H.V. Hema Kumar

Received : 22.12.2019; **Accepted :** 27.03.2020

See end of the Paper for authors' affiliation

Correspondence to :

K. Kishan
Department of Soil and Water Engineering, College of Agricultural Engineering,
Bapatla (A.P.) India
Email: kishancae@gmail.com

■ **KEY WORDS :** Water, Agiculture, Policy, Food supply

■ **HOW TO CITE THIS PAPER :** Kishan, K. and Hema Kumar, H.V. (2020). Conjuntive use planning of surface and ground water resources . *Internat. J. Agric. Engg.,* **13**(1) : 137-144, **DOI: 10.15740/HAS/IJAE/13.1/137-144.**

Water is one of the most important recourse on the earth. The resource supports life on the planet, as well as aids in economic, agricultural and industrial growth. Irrigation is one of the most important uses of water. This has played a major role in poverty alleviation by providing food security, protection against famine and extends opportunity for employment both on and off the farm. It was massive irrigation infrastructure created through the net works canal and wells for ground water utilization that has helped achieve the self-sufficiency in food in the country.

The integrated use of surface and groundwater resources, commonly termed conjunctive use is the application of programming techniques for optimum utilization of both water resources in a regional scale. The world population is increasing faster than the food supply. The population of India is expected to stabilize around 1640 million by the year 2050. Agriculture uses about 70 to 80 per cent of total available water. Water is recognized as a vital resource both for livelihood, food security and environmental sustainability. If sufficient water resources are available, it is possible to increase the intensity of cultivation upto 300 per cent or more and large extent of areas of waste/fallow lands can be brought under cultivation, which will solve the problem of food shortages for the increasing population.

The ever increasing demand for irrigation water, everywhere, has now focused national attention and public interest on utilization of existing water supplies, integrated irrigation water conservation and management policy and practices. The optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture. Factors affecting on irrigation water are multiple. Among the most important factors are irrigation scheduling, irrigation water supply systems, water application systems at field level and its management. Now-a-day's irrigation is costly and scare input in agriculture and plays an important role in increasing agricultural production. As a result, groundwater can play a powerful drought-mitigating role when surface and groundwater are managed and used conjunctively.

In the situations identified above, the key benefits of investing in conjunctive use are as the following:

– Improved sustainability of groundwater irrigation in regions of intensive groundwater use with inadequate availability of runoff for recharge

– Use of poor-quality water to increase agricultural production, employment and income

Review of literature:

Tyagi (1988) conducted a study on planned development and use of saline ground water in conjunction with limited fresh water supplies is essential in arid and semi-arid regions for reclamation and management of waterlogged saline lands. A decision model so developed is applied to a typical waterlogged saline area in the command of Western Yamuna Canal in Haryana (India) to determine optimal land and water allocation and the resulting salt and water balance in the unsaturated (crop root zone) and saturated zone (aquifers). The programme indicated that progressive development of ground-water will assist in reclamation of waterlogged saline lands and can increase farm income.

Coe *et al.* (1990) conducted a study on conjunctive use of surface water and ground water can usually increase yields at lower costs than more dams and reservoirs operated separately.

Onta *et al*. (1991) presented a three-step modeling approach for comprehensive analysis of the planning problem involving integrated use of surface and ground water in irrigation for a Bagmati River Basin in Nepal.

Epperson *et al*. (1993) where water available for irrigation is limited. The purpose of the study was to identify optimal irrigation thresholds for several maize irrigation Strategies in the southeastern USA. Using dynamic programming (DP), Decisions among six possible thresholds were made for each of five maize Growth stages. Net returns were maximized subject to a constraint on the Total amount of irrigation. Net returns and irrigation amounts were determined For each growth stage using the growth simulator CERES-Maize. Net returns were computed by stage using the futures price for grain and constant ratio of grain yield to biomass. Net returns and water consumption were also computed for fixed threshold irrigation strategies. Dynamic irrigation Strategies with differing thresholds for each growth stage produced higher average net returns and required less irrigation water than the best fixed Threshold irrigation strategies. Further, irrigation amounts with the dynamic Strategies were held below the maximum irrigation level. Irrigation amounts for the fixed strategies.

Atwater *et al.* (1995) conducted the author's historical analysis of conjunctive use in Southern California provides an excellent overview of the key role played by the imported supplies to improving the management of ground-water aquifer systems. Today, the Southern California water supply system has developed an intricate management structure for importing water, regional wholesale distribution systems, and local ground-water management and storage of imported supplies. The programme, called seasonal storage service, provides for significantly lower cost Metropolitan water if stored during the off-peak system.

Onta *et al.* (1995) developed a linear programming based optimization and simulation model and applied it to a typical diversion type irrigation system for land and water allocation during dry season for Kansas Irrigation system, Nepal. Optimum cropping pattern for different management strategies are obtained by LP model for different irrigation efficiencies and water availability scenarios. The simulation model yielded the risk related irrigation system performance measures (reliability, resiliency and vulnerability) for defined management policies.

Vishwanadh and Reddy (1995) conducted a study on conjunctive use of groundwater and surface water in Krishna Delta for irrigation. The main points considered were, the availability of groundwater and the scope for recharge of groundwater. In Krishna Delta, there is enough scope for utilization of groundwater for agriculture purpose, subject to the quality considerations. The quality of groundwater in different regions of Krishna Delta was examined to adopt a suitable mix of groundwater and surface water in their conjunctive use and thereby conserved the storage at Nagarjuna Sagar reservoir for utilization in upper reaches.

Chandra (1996) developed a linear programming optimization model to maximize the net returns under the constraints of land, water, canal running hours, canal capacities and cropped area to recommend an optimal canal operation schedule for Gambhiri irrigation system among the proposed operation plans in which optimal allocation takes place at different stages of water distribution.

Frizzone *et al.* (1997) conducted experiment onlinear programming model to optimize the water resources in irrigation projects: "Senator Nilo Coelho Project". For the total monthly water availability of 9,861,040 m^3, the total annual water availability of 66,644,500 m^3 became an effective restriction to the increase of the net income of production system in the SNCP. For maintaining the total monthly water availability of 9,861,040 m^3, annual volumes lower than 88,338,983 m^3 were used fully to reach the optimal solution, and that higher volumes than this limit, did not increase the net income. The optimization model estimated a net income of 52.34 per cent higher than the traditional cropping pattern used in the SNCP, considering the agriculture year of 1992.

Singh *et al.* (1998) developed resource allocation model using linear programming technique for Badliya distributory command of Mahi Bajaj Sagar Project for integrated resource planning. Land allocation was made under different crops for production maximization, net benefit maximization and investment minimization. The net benefit was worked out to be Rs. 8844438 as compared to net benefit value of Rs. 7155738 for existing cropping pattern.

Mohan *et al.* (1998) developed stochastic linear programming model to determine optimal cropping pattern at different levels of dependable inflows. Suitable statistical distributions have been fitted for inflows into the reservoir for each month. This model maximizes net benefit and derives both optimal storages and releases for various inflow scenarios.

Srinivas Raju and Nagesh Kumar (2000) developed a linear programming irrigation planning model for the evaluation of irrigation development strategy and applied to a case study of Sri Ram Sagar project, Andhra Pradesh, with the objective of maximization of net benefit. Inflows at four levels of dependability *viz.*, 75 per cent, 80 per cent, 85 per cent and 90 per cent were considered to obtain various possible optimal cropping patterns and optimal operating policies. It was observed that net benefits at 75 per cent dependability level were 68.8 per cent more than those at 90 per cent dependability level.

Sethi *et al.* (2002) reported that due to increasing trend of intensive rice cultivation in a coastal river basin, crop planning and groundwater management are imperative for the sustainable agriculture. A groundwater balance model has been developed considering mass balance approach. The components of the groundwater balance considered are recharge from rainfall, irrigated rice and non-rice fields, base flow from rivers and seepage flow from surface drains. In the second phase, a linear programming optimization model is developed for optimal cropping and groundwater management for maximizing the economic returns. The models developed were applied to a portion of coastal river basin in Orissa State, India and optimal cropping pattern for various scenarios of river flow and groundwater availability was obtained.

Azaiez (2002) developed a multi-stage decision model for the conjunctive use of ground and surface water with an artificial recharge. It is assumed that certain supply and a random demand. Opportunity costs for the unsatisfied demand. Was integrated explicitly the importance weight attributed by the decision-makers to the final groundwater level at the end of the planning horizon. Was also interoduced.It was shown that the problem be formulated as a convex programme with linear constraints. With a hypothetical example the model was explained.

Ahmed hafi (2002) In this study, one of the key economic issues faced by the managers of the two water boards in the Burdekin River Delta is the allocation of surface water between immediate use on farm for irrigation and storage in the aquifer for future use. Because of the significance of the interaction between surface water and groundwater and the return flow externalities within the delta, policies on surface water and groundwater need to be determined simultaneously. A model is formulated of the dynamic system of surface water and groundwater in the delta with water demand, groundwater extraction cost and stochastic recharge and surface water availability. The optimal pumping/artificial recharge policies for each state of the joint surface water and groundwater system is derived for the two hydro geologically different parts of the delta and for each area this policy is applied over a large number of years to derive the expected development over time of extraction/ artificial recharge and the state of the groundwater system. The implications of the optimal pumping/artificial recharge policy for any review of existing allocations of surface water and groundwater are discussed.

Karamouz *et al*. (2004) developed a dynamic programming optimization model for conjunctive use planning. The objective function of this model is developed to supply the agricultural water demands, to reduce pumping costs and to control groundwater table fluctuations.

Rao *et al*. (2004) have developed a regional conjunctive use model for a near-real deltaic aquifer system, irrigated from a diversion system, with some reference to hydro geo climatic conditions prevalent in the east coastal deltas of India. Water resources are sufficiently available in these regions under average monsoon rainfall conditions, but their distribution in space and time has been ever challenging to water managers.

Sundararajan *et al.*(2004) imertigated the formations associated with an gneiss and sandstones near Tiruvuru, Krishna district, Andhra Pradesh which are generally favorable for groundwater occurrence employing seismic refraction method. Results were examined by correlating the signals with local geology, bore well data and other available information in order to improve the reliability of interpretation.

Vedula *et al.* (2005) conducted on a mathematical model is developed to arrive at an optimal conjunctive use policy for irrigation of multiple crops in a reservoir-canal–aquifer system. The integration of the reservoir operation for canal release, ground water pumping and crop water allocations during different periods of crop season (intra seasonal periods) is achieved through the objective of maximizing the sum of relative yields of crops over a year considering three sets of constraints: mass balance at the reservoir, soil moisture balance for individual crops, and governing equations for ground water flow. A two-dimensional isotropic, homogeneous unconfined aquifer is considered for modeling. The aquifer response is modeled through the use of a finite element ground water model. A conjunctive use policy is termed stable when the policy results in a negligible change in the ground water storage over a normal year. The applicability of the model is demonstrated through a case study of an existing reservoir command area in Chitradurga district, Karnataka State, India.

Hassan *et al.* (2005) conducted experiment on use of linear programming model to determine the optimum cropping pattern, production and income level: A Case Study from Dera Ghazi Khan Division. They concluded that Dera Ghazi Khan Division is more or less operating at the optimal level. Cotton was the only crop which, gained acreage. As a result of optimal cropping pattern, farm income increased by 2.91%.

Hassan *et al.* (2005) conducted experiment on use of linear cropping model to determine the optimum cropping pattern: A case study of Punjab. The results show that the irrigated agriculture in the Punjab, Pakistan is more or less operating at the optimal level. Over all cropped acreage in the optimal solution decreased by 0.37% as compared to the existing acreage.

Srinivasulu and Satyanarayana (2005) developed a Linear Programming (LP) model for allocation of land and water resources to different crop activities in canal irrigated saline groundwater areas for maximizing the net returns using LINGO 6.1 software. The model predicts that even in the case of changes in irrigation water supply, it will not be economical to change the cropping pattern.

Pulido-Velazquez *et al.* (2016) conducted integrated hydrologic-economic modeling framework for optimizing conjunctive use of surface and groundwater at the river basin scale. The use of an economic objective function, maximizing the net economic value of water use, provides solutions that optimize economic efficiency in water resources management. Constraints guarantee the feasibility and sustainability of suggested operations. A non-linear optimization model is presented for the Adra River Basin system Spain. Model results suggest a variety of water management and operation strategies and indicate where significant the economic benefits can be obtained through capacity expansion.

Khare *et al.* (2006) studied the quantity and quality of available water resources have been recognized as limiting factors in development of most of the arid and semi arid regions. Optimal use of available surface and groundwater, in any canal command area would result in their better utilization by maximizing the benefits from the crop production. In the present paper, the feasibility of conjunctive use management is analyzed using a mathematical model in the Sapon irrigation command area of KulonProgo Regency, Yogyakarta province. The LINDO 6.1, optimization package has been used to arrive at optimal allocation plan of surface water and groundwater. The results indicate that conjunctive use options are feasible and can be easily implemented in the area, which would enhance the overall benefits from cropping activities.

Khare *et al*. (2007) reported that shortages of surface water supplies necessitate development of groundwater in many canal commands. Groundwater can be used optimally in conjunction with surface supplies in a conjunctive use system. They reported about potential and feasibility of conjunctive use planning for one of the proposed link canal, Krishna (Nagarjunasagar)–Pennar (Somasila) canal, under peninsular rivers development as a part of India's ambitious river linking programme, has been explored. The LINDO 6.1, optimization package has been used to arrive at optimal allocation plan of surface water and groundwater. The results substantiated that conjunctive use planning is beneficial and feasible for the proposed canal command.

Raj and Sudhakar (2007) developed an optimal operational policy of three reservoir system as a single unit. The 75 per cent dependable monthly inflows were estimated and the irrigation water requirements were obtained using CROPWAT. A multi- reservoir linear programming model to maximize irrigation released with the physical constraints of the system had been formulated and solved using linear interactive general optimizer (LINGO). The results indicate that the inflows are not sufficient to meet the demands and therefore conjunctive use of groundwater is suggested for supplementing the water requirements of the system.

Azamathulla (2009) developed a Linear Programming (LP) model and applied to real-time reservoir operation in an existing Chiller reservoir system in Madhya Pradesh, India. The developed model was successfully applied to irrigation supporting reservoir systems. The model ensured an optimum reservoir release over different time periods. The model ensured optimum allocation of the available water for different crops in the fields. The optimum cropping pattern model used in the study allows only productive irrigation, so that the water wastage is reduced.

Babu *et al.* (2009) reported that the main objective of improving water use efficiency will be spreading irrigation benefits to the tail end farmers also. In this Pilot area 205 ha Canal Command area fewer than 24L Minor Canal with main crop of paddy was taken as study area and measuring the water from different available water resources such as Canal and open wells. By adapting certain Canal rehabilitation works such as renovation of drop structures, field channel regulators and lining at vulnerable places and crop management practices, water use efficiency was improved in the pilot area. The results showed that increase in yield from 5.4 to 5.7 t/ha and reduced water used from 1530 to 1147 mm and improved WUE from 3.5 to 4.9 kg/ha-mm.

Foster *et al*. (2010) conducted a study to provide a strategic guide to current practices of conjunctive use of groundwater and surface water resources for both irrigated agriculture and urban water-supply in the developing world and the great potential that planned conjunctive use has as an adaptation strategy to accelerated climate change.

Montazar *et al*. (2010) coupled an integrated soil water balance algorithm to a non-linear optimization model in order to carry out water allocation planning in complex deficit agricultural water resources systems based on an economic efficiency criterion. The LINGO 10.0, optimization package has been used to evolve at optimal allocation plan of surface and ground water for irrigation of multiple crops. Various scenarios of conjunctive use of surface and ground water along-with current and proposed cropping pattern have been explored. Some deficit irrigation practices were also investigated. The results indicate that conjunctive use practices are feasible and can be easily implemented in the study area, which would enhance the overall benefits from cropping activities.

Mahjoub *et al.* (2011) worked on conjunctive use of surface and groundwater in the Maraghe area was investigated. The objective function used for the overall conjunctive use model was maximizing sum of relative yields of crops in the command area. Declining groundwater levels was selected as criteria of groundwater limitation. The simulation was done for four years and began by a dry year to normal year.

Mahjoub *et al.* (2011) worked on imertigated conjunctive use of surface and groundwater in the Maraghe area. The objective function used for the overall conjunctive use model was maximizing sum of relative yields of crops in the command area. Declining groundwater levels was selected as criteria of groundwater limitation. The simulation was done for four years and began by a dry year to normal year.

Jafari and Das (2013) conclude the conjunctive use model is constructed as an allocation model of surface water and ground water which is constrained by system dynamics comprising of recharge-discharge boundaries of ground water aquifers and inflow-outflow of surface water bodies. The resulting non-linear programming model is solved by employing Sequential Unconstrained Minimization Technique. Finite element method is employed for solving the governing groundwater flow equation and the resulting hydraulics are incorporated in the optimization model by adopting unit response matrix technique. The results indicate that the developed mathematical model is robust and capable of simulating the system hydraulics satisfactorily and is responding to the demand variations, cost variations, surface water mass balance and ground water draw down constraints reliably.

Majeke *et al.* (2013) reported that farm planning problems are much more complex. Farmers do not only produce different crops, but also have to choose among a variety of ways of producing them. Crop planning may involve choices about varieties, planting dates, and fertilizer and pesticide treatments. Linear programming has proved a very flexible tool for modeling these kinds of complexities. In this paper, a linear programming model was developed to determine the optimal crop combination for a rural farmer. Crops considered were maize, soya beans and cotton. The model produced an optimal crop combination that gives higher income than that obtained from the farmer's plan. The income difference was 72.79 per cent.

Majeke (2013) concluded that farmer's profit cannot be maximized without optimum cropping patterns, which ensure efficient utilization of available resources. Farmers often follow their instinct and experience to handle this problem. This does not guarantee optimal solutions. In this study a linear programming model was applied to calculate the crop acreage, production and income of a model a farm in Zimbabwe. The study was conducted on 32.55 hectares of land of which 27.55 hectares is rain fed and 5 hectares is irrigated. Crops and livestock included were maize, potatoes and pigs. The results showed that rain fed maize gained acreage by 233%. The overall optimal crop acreage increased by 85%, while the income increased by 33% as compared to the farmer's plan.

Regulwar and Pradhan (2013) developedsurface and groundwater are related systems. They can be used conjunctively to maximize the efficient use of available resources. In their study, an irrigation planning model is formulated by considering the conjunctive use of surface and groundwater. The resources in the present model, *i.e.* the area, surface water and groundwater availability are represented by fuzzy set. The linear membership function is used to fuzzify the objective function and resources. The model is applied to a case study of Jayakwadi project and solved for maximization of the degree of satisfaction (λ) which is 0.546.

Sethi *et al.* (2014) concluded that the conjunctive planning of irrigation through bore wells, dug wells and water harvesting structures along with farmers' participatory approach in Pattamundai canal command area of Odisha could increase cropping intensity from 151 per cent to 300 per cent with high value and less water requirement crops. Interventions showed that during long dry spell period in *Kharif* season and non-availability of canal water, use of groundwater upto 20 % of the crop water demand could enhance crop yield upto 21 %. Utilizing water from dug well, for three crops (short duration paddy- potato/ radish- bitter gourd) in a year recorded highest net return of Rs. 87368/ha against two crops (paddy - brinjal) without depletion of groundwater level. Further, highest water productivity (kg fruit yield/m^3 of water used) was observed in potato (6.67-8.41) followed by brinjal (4.06-4.42).

Conclusion:

Availability of alternative water supplies, used separately or conjunctively, can improve water-service reliability and flexibility and provide increased control of quantity, quality, and costs. Conjunctive use can increase yields at lower costs than more dams and reservoirs and furnish positive ancillary impacts, such as a stored supply near demand centers, increased drainage, and long-term ground-water quality improvement.

Authors' affiliations:

H.V. Hema Kumar, Department of Soil and Water Engineering, College of Agricultural Engineering, **Bapatla (A.P.) India**

■ REFERENCES

Ahmed Hafi (2002). Conjunctive use of groundwater andsurface water in the Burdekin delta area. *Australian Bureau of Agricultural & Resource Economics.*1-26.

Atwater, Richard W., Palmquist, Linda and John Onkka (1985). The West Basin desalter project: A viable alternative. *Desalination,* **103** (1–2) : 117-125.

Azaiez, M.N. (2002). A model for conjunctive use of ground and surface water with opportunity costs. *European J. Operational Res.,* **143**: 611–624.

Azamathulla, V. (2009). Optimal cropping pattern for a basin in India. *J. Irrigation & Drainage Div*, ASCE, **103** (1): 53-70.

Babu, C., Koodalingam, K., Natarajan, U.S., Shanthi, R.M. and Govindaraj, P. (2009). Genetic enhancement of sugarcane (*Saccharum* spp. hybrids) for resistance to red rot disease and economic traits. *Indian J. Agric. Sci.,* **4** : 97-107.

Basharat, M., Umair Ali, S. and Aftab, H. (2013). Azhar. Spatial variation in irrigation demand and supply across canalcommands in Punjab: a real integrated water resources management challenge. *Water Policy Uncorrected Proof, 1–*

25.

Chandra, A. (1996). Optimal canal scheduling in Gambhiri irrigation system. Ph.D. Thesis. Maharan Pratap University of Agriculture, Udaipur, Rajasthan (India).

Coe, J.J. and Fellow, ASCE (1990). Conjunctive use advantages, constraints, and examples. *J. Irrigation Drainage Engg.,* **116** : 427-443.

Epperson , James E., Hook , James E. and Mustafa , Yasmin R. (1993). Dynamic programming for improving irrigation scheduling strategies of maize. *Agricultural Systems,* **42** (1–2) : 85-101.

Frizzone, J.A., Coelho, R.D., Dourado – Neto, D. and Soliant, R. (1997). Linear programming model to optimize the water resource use in irrigation projects: An application to the Senator Nilo Coelho project. Science Agriculture, Piracicaba 54, 136-148.

Foster, S., Steenbergen, F.V. and Zuleta, J. (2010). Conjunctive Use of Groundwater and Surface Water from spontaneous coping strategy to adaptive resource management. *www.worldbank.org/gwmate*.

Gupta, C.P., Ahmed, S. and Rao, G.V.V.S. (1985). Conjunctive utilization of surface water and ground water to arrest the water –level decline in an alluvial aquifer. *J. Hydrol.,* **76** (1985) : 351-361.

Hassan, I., Ahmed, B., Akhter, M. and Aslam, M.M. (2005). Use of linear programming model to determine the optimum cropping pattern. A case study of Panjab. *J. Environmental Agric. Food Chem.,* **4** (1): 841-850.

Hassan, I., Raza, M., Khan, A., A Izhar and Ilahi, R. (2005). Use of linear programming model to determine the optimum cropping pattern, production and income level: A Case study from Dera Ghazi Khan division. *J. Agril. Soc. Sci.,* **1**(1):32-34.

Jafari, Ashfaque and Das, G Jagmohan (2013). Integrated conjunctive use model. *Internat. J. Engg. Res. & Sci. & Tech.,* **2** (3) : 151-163.

Karamouz, M., ASCE, F., Kerachian, R. and Zahraie, B. (2004). Monthly water resources and irrigation planning: case study of conjunctive use of surface andgroundwater resources. *J. Irrigation Drainage Engg.,* **130**(5): 391-402.

Khare, D., Jat, M.K. and Ediwahyunan (2006). Assessment of conjunctive use planning options: A case study of Sapon irrigation command area of Indonesia. *J. Hydrol.,* **328** : 764-777.

Khare, D., Jat, M.K. and Sunder, J.D. (2007). Assessment of water resources allocation options conjunctive use planning a link canal command. *Resources, Conservation & Recycling* **51** (2007) : 487–506.

Mahjoub, H., Mohammadi, M.M. and Parsinejad, M. (2011). Conjunctive use modeling of groundwater and surface water. *J. Water Resource & Protection,* **3** : 726-734.

Majeke, F. (2013). Use of linear programming model to determine the optimum cropping pattern: a case study of a model A2 farmer in zimbwe. *ZENITH Internat. J. Multidisciplinary Res.,***3** (6):69-73.

Majeke, F., Michael Ticharwa Mubvuma, Kasirayi Makaza, and Jackqeline Mutambara (2013). Optimum combination of crop farm activities: Application of a Linear Programming Model to a Rural Farmer in Zimbabwe. *Greener J. Economics & Accountancy,* **2**(2) : 058-061.

Mohan, S., Raman, H. and Nagarajan, K. (1998). Stochastic linear programming model for irrigation planning. *J. Indian Water Resources Society,* **18**(4): 28-34.

Montazar, A., Riazi, H. and Behbahani, S.M. (2010). Conjunctive Water Use Planning in an Irrigation Command Area. *Water Resources Manage,* **24**:577–596.

Onta, R.P., Gupta, D.A. and Harboe, R. (1991). Multistep planning model for conjunctive use of surface and ground water resources. *J. Water Resources Planning & Mgmt.,* **117** : 662-678.

Onta, P.R., Loof, R. and Banskota, M. (1995). Performance based irrigation planning under water shortage. *Irrigation & Drainage Systems,* **9** : 143-162.

Pulido-Velazquez, M., Sahuquillo, A. and Andreu, J. (2006). Economic optimization of conjunctive use of surface and groundwater at the basin scale. J. Water Resour. Plan Manage, **132** (6) : 454–467.

Rao, S.V.N., Bhallamudi, M.S.B., Thandaveswara, S. and Mishra, G.C. (2004). Conjunctive use of surface and groundwater for coastal and deltaic systems. *J. Water Resources Planning & Mgmt.,* **130** : 255-267.

Regulwar, D.G. and Pradhan, V.S. (2013). Irrigation planning with conjunctive use of surface and groundwater using fuzzy resources. *J. Water Resource & Protec.,* **5** : 816-822http://dx.doi.org/10.4236/jwarp.5: 816-822.

Sethi, L.N., Nagesh Kumar, D., Panda, S.N. and Mal, B.C. (2002). Optimal crop planning and conjunctive use of water resources in coastal river basin. *Water Resources Mgmt.,* **16**(2):145:169.

Sethi, L.N., Panda, S.N. and Nayak, M.K. (2006). Optimal crop planning and water resources allocation in a coastal groundwater basin, Orissa, India. *Agric. Water Mgmt.,* **83**(16):209-220.

Sethi, R.R., Singandhupe, R.B. and Kumar, Ashwani (2014). Conjunctive Planning of Surface and Groundwater Resources in Canal Command Area of Odisha-A Success Story. *IOSR J. Agric. & Veterinary Sci.*, 2319-2372. **7** (9) Ver. III : 43-48.

Singh, A.K., Singh, J. and Singh, R. (1998). Optimum utilization of resource for crop production-A case study. *J. Indian Water Resources Society*, **18**(4): 66-69.

Srinivasulu, A.and Satyanarayana, T.V. (2005). Development and application of LP model for conjunctive use of water resources in saline groundwater areas. *IE (I) Journal –AG*. **86** : 40-44.

Srinivas Raju, K. and Nagesh Kumar, D. (2000). Optimum cropping pattern for Sriram Sagar Project a linear programming approach. *J. Appl. Hydrol.*, **13** (1&2): 57-67.

Tyagi, N.K. (1988). Managing salinity through conjunctive use of water resources. *Ecol. Modeling*, **40**: 11-24.

Sundararajan, N., Srinivas, Y., Narasimha Chary, M., Nandakumar, G. and Hanmantha Chary, A. (2004). Delineation of structures favourable to groundwater occurrence employing seismic refraction method—A case study from Tiruvuru, Krishna district, Andhra Pradesh. *J. Earth System Sci.*,**113** : 259–267.

Vedula, S., Mujumdar, P.P. and Chandra Sekhar, G. (2005). Conjunctive use modeling for multicrop irrigation. *Agric. Water Management*, **73**: 193-221.

Vishwanadh, G.K. and Reddy, D.V. (1995). Conjunctive use of groundwater and surface water in Krishna delta for Irrigation. *J. Inst. Engg.*, **75**: 197-202.