Chapter 6

Conclusions and Scope for Future Work

6.1 General

Determining the timing and quantity of irrigation water for a crop /s is important, for any decision making in irrigation scheduling. Factors influencing the irrigation scheduling are type of crop, soil, climate and availability of water. Adequate and timely water supply to crops would give optimal yield. Maintaining adequate soil water content in the root zone, throughout the growth period without limiting the crop growth is a challenging task. The scheduling of irrigation is complex, as decisions to irrigate needs to be decided on crop's sensitivity to water deficits, in different periods of its growth. Large numbers of models are available for computing soil water balance, and generating improved irrigation schedules. Computer models which are appropriate tools for developing and evaluating alternative irrigation strategies are used for this study. WEAP-MABIA model used in this study, to find actual evapotranspiration using Penman Monteith Method, and dual crop coefficient approach is found to be of great use. Penman Monteith model is found very useful, to estimate daily potential evapotranspiration using daily climatological data. Further, dual crop coefficient approach of FAO-56, separately computes soil evaporation, or surface moisture depletion, and transpiration, under normal and water stress condition. Actual evapotranspiration and potential evapotranspiration is found, for fourteen major crops in region I and four blocks of region II, to understand the impact of various irrigation strategies. Alternative six irrigation strategies i.e. Strategy S I: Fixed irrigation interval with fixed depth, Strategy S II: Fixed irrigation depth at 100 per cent of RAW, Strategy S III: Model determined no stress conditions, Strategy S IV: Protective irrigation, Strategy S V: Deficit irrigation, and Strategy S VI: Combined irrigation strategies have been evaluated and results are found to be encouraging. The model determined, no stress irrigation strategy maximizes yield of crop, prevents runoff, and deep percolation thus has been used for comparing the strengths and weakness of other strategies, which is found to be helpful. WEAP-MABIA can prove to be of great help in determining irrigation requirements in real time condition. Maximizing yield with water savings under various scenarios could be achieved with its help.

6.2 Specific Conclusions and Recommendations

Actual crop evapotranspiration estimated using Penman Monteith, and dual crop coefficient method for fourteen crops grown is used in estimating the water demand in region I and four blocks of region II. Alternative, six irrigation strategies has been developed and evaluated with motive of maximizing yields with water savings in a given water supply, for various scenarios in the study area. The study was carried out from year 2003 to 2010 and the work was limited to16 blocks of region I and 4 blocks of region II in Sardar Sarovar Project Area. Following conclusions and recommendations are drawn based on this study.

1. FAO-56 Penman Monteith model to estimate reference evapotranspiration coupled with dual crop coefficient approach (MABIA method which is incorporated in WEAP model) has been used for precise estimation of crop water requirement, which is very essential for inputs in soil moisture balance under irrigation. FAO-56 Penman Monteith model is found very useful, to precisely estimate daily potential evapotranspiration using daily climatological data. The dual crop coefficient approach helps in computing, separately soil evaporation and transpiration, under normal and water stress condition.
2. After starting of precipitation, part of precipitation (i.e. effective precipitation) enters into the root zone, which increases the soil moisture. SCS method is found to be useful in estimating effective precipitation, for soil moisture balance model.
3. Soil moisture balance computation on daily basis plays an important role, for evaluation of irrigation scheduling, crop yield, and recharge to groundwater. The daily variation in soil surface wetness, soil moisture profile, due to frequent or light wetting, because of rainfall and irrigation has a significant impact on crop evapotranspiration.
4. Examining the yield response in field and / or controlled experiments to varied water applications is laborious, expensive and time consuming. Neither it is possible to carry out all combinations of scenarios like normal, wet and dry season, and their effect in yields. In view of this background, soil moisture balance model coupled with yield model is a useful tool, in assessing various irrigation strategies.
5. Water stress is not constant throughout the growing period, but varies in magnitude at different periods, thus relative yield fractions requires to be calculated at smaller time steps. In MABIA method relative yield fractions is calculated on daily time step, and aggregated for the season, is useful in estimating the yield accurately.

6. Under, water stress condition the soil moisture depletion may reduce below total available water. Under, this condition the daily yield fraction tends to zero. In such case, yield is deduced to be zero during the season.
7. Irrigation strategies developed for various scenarios with alternative sets of assumptions, help to assess and predict the irrigation demand for different policies. On evaluation and comparison of the different irrigation strategies, the water use efficiency, and yield for major crops is obtained, which helps in deciding appropriate strategy for realizing maximum gains and water saving.
8. Irrigation scheduling, if applied based on the soil water status would give high yields. However; the irrigation depth range varies significantly during wet and dry years, for all such strategies, which use irrigation trigger method for soil moisture depletion levels, to reach certain percent of readily available water, or total available water
9. Irrigation given on the basis of growth stages, show water stress specifically in initial stages. Further, irrigation of smaller depth (as observed in Wheat), applied frequently during different stages would enhance yield, water use efficiency, and irrigation water use efficiency, rather than infrequent and large quantity of irrigations.
10. During simulation for the rice crop, the standing water over the ground is not considered, and hence the excess irrigation or rainfall after saturation of soil generates surface run off. In actual practice, such surface run off is prevented, by constructing the bunds, and this reduces the requirement of daily irrigation
11. Traditional irrigation practice of fixed irrigation interval with fixed irrigation depth (Strategy S I) causes either over irrigation, or moisture stress conditions, leading to reduction in yield and water use efficiency. However; its simplicity of usage and assurance of potential yield, makes it more prevalent amongst the farmers. The irrigation water demand is independent of climatic variations. Crops under this strategy get over irrigated in Kharif season, as the irrigation interval can't be adjusted, according to the prevailing soil moisture conditions due to the rainfall events. However, reduction of irrigation depth during the initial vegetative stage can restrict over irrigation to certain extent.
12. In areas where ground water is shallow, and showing rising trend; the strategy S I is recommended during Kharif season.
13. Strategy S II has large variability in range of irrigation depth, indicating the sensitiveness of strategy towards rainfall, soil moisture, and climatic conditions. In strategy S II, if fixed depth irrigation is much greater than RAW depth, it results in greater losses, due to percolation, leading to lower irrigation water use efficiency.

Amount of irrigation depth needs to be carefully decided, for strategy S II in blocks having sandy clay soil, because the value of RAW is low. In initial vegetative stage the irrigation depth in various soils, needs to be selected cautiously.

14. In strategy S III, irrigation is applied equivalent to soil moisture depletion to prevent water stress condition, which results in highest yield of crop with maximum water saving for all the crops, and is the best strategy amongst the recommended six strategies. However; in initial vegetative growth stage, frequent irrigation is required. As the timing of irrigation, is highly dependent on climatic variation and rainfall, its implementation is challenging. Irrigation with this strategy is feasible, if irrigation is triggered by monitoring the soil moisture deficit, with help of automated sensors installed to assess the soil moisture status. If last irrigation is cut off early, as for crops like wheat, sugarcane etc, to obtain good yield, as per prevailing practices, moisture stress may be observed.

15. Strategy S IV ensures minimal yield with protective irrigation for crops, where the farmers are dependant mostly on rainfall, and would resort to irrigation only just to save the crop. This strategy is useful for marginal farmers who don't own wells/tube wells but buy water from other farmers, and in situations, when canal water is not available. In case of dry year/unavailability of sufficient canal water; protective irrigation could be tried with reduced fixed depth of irrigation. In strategy S IV the crops having critical permissible soil moisture depletion factor 'p' less than 80% (Rice, Sugarcane etc) would have significant yield reduction. Reasonably good yield is attained for crops that are drought resistant like bajra, castor etc on irrigating with this strategy.

16. To obtain better yields with less water; regulated deficit irrigation (Strategy S V) be applied during a specific growth stage/s depending upon crop. Mild water stress during different growth stage/ s, reduces the yield marginally for some crops with significant increase in irrigation water use efficiency in comparison to traditional practices.

17. Strategy S VI overcomes some of the difficulties faced in other strategies with benefits of ease in implementation, reasonable good yield, and reduced irrigation depths.

18. Crops which are grown with the onset of monsoon may be given reduced irrigation, or applied no irrigation water in initial vegetative period, with exception in strategy S III to stop over irrigation. Mild yield reduction is expected due to this approach.

19. Strategies best suited and recommended in order of merit for attaining significant yield and water savings simultaneously for Rice Tuver, Chana, Cabbage, Castor, Cotton, Kharif Groundnut, and Tobacco crops are S III, followed by S VI, S II and SI.
20. Tuver crop has no significant reduction in average yield in strategies S VI, and S II, although former strategy uses slightly more irrigation water.
21. Irrigation strategy S IV for Rice, Sugarcane, Cabbage, and Tobacco crops show comparatively more reduction in yield due to its sensitivity to moisture deficit. This strategy could only be recommended with caution, for aforementioned crops to farmers.
22. In Cabbage, and Chana the variability in irrigation depth for strategy S II is significant, indicating its sensitiveness towards climatic and soil moisture conditions.
23. In case of Castor crop, rate of decrease in average irrigation depth, for irrigation strategies SV, and S IV does not have similar impact in rate of decrease of the average yield for both strategies. This can be of great help, while deciding irrigation during dry years for crops like Castor, which are relatively drought resistant.
24. Strategies S II, S VI, and S I can be recommended in order of merit for Wheat, Maize and Sugarcane crop, to attain higher yields with significant water savings. In case of earlier withdrawal of monsoon, or poor monsoon, when sufficient canal water is unavailable strategies S IV and S V can be recommended for Wheat, and Maize. Maize crop is sensitive to moisture stress, thus reducing irrigation below the optimum level has high yield reduction.
25. Strategies best suited for Jowar, and Bajra crop are S III, followed by S II, and S IV, as optimum yield is attained with little or no irrigation, depending upon wet or dry scenarios.
26. The variability in ground water demand indicates the sensitiveness of the irrigation strategies towards rainfall, soil moisture and climatic conditions. Significant variability in ground water demand is noticed for crops Castor, Cotton, Groundnut, Sugarcane, Tobacco, and Tuver. The initial soil moisture conditions, due to rainfall in post monsoon significantly influence the fluctuations of water demand in month of November, for crops Castor and Cotton in region I and II of Sardar Sarovar Project. Ground water demand for Kharif Bajra is nil, during normal and wet years with exception, delay in monsoon for most of the irrigation strategies. Ground water demand for Kharif Jowar is nil, during first two months in most of the strategies, but high variability are noticed thereafter.

27. Irrespective of dry or wet scenarios, peak water demand in study area under strategy S III is month of October, while for strategy S VI it is December.
28. Fluctuations of canal water demand under strategy S VI is noticed, during month of November, afterwards the demand is same, except year 2008
29. The Kharif crops if not irrigated under less or delayed rainfall than their yield is affected. Various irrigation strategies suggested for irrigating Kharif crops utilize only groundwater, whereas canal water is used post Kharif season. Conjunctive use of surface, and ground water in the area can withheld the rising trend of water table in certain pockets of the region.
30. Large amount of water is lost due to deep percolation in the initial and development stages in most of the strategies, except model determined strategy S III, where flow to groundwater is nil. Reasonable water saving criteria requires to be taken into consideration, before recommending a particular strategy.
31. Results of the statistical analysis show that strategy S III is best suited for all crops. Irrigation with strategy S III is feasible, if irrigation requirement is triggered according to soil moisture deficit with help of automated sensor installed, to assess the soil moisture status. This strategy is difficult to implement under canal irrigation.
32. The second best strategy is S VI, S II, or S I, depending upon crop however; if water savings is also considered together, than S VI is better placed than other strategies.
33. Information system model integrated with WEAP will assist the planners in monitoring and taking suitable decisions, for computing crop water requirements for management of irrigation water demand.

6.3 Following Major Contributions Can Be Attributed to the Present Research Work

1. Penman Monteith method coupled with Dual crop coefficient, SCS model and Soil moisture balance model are used, for major crops of Sardar Sarovar Project region I with agro-climatic data from the year 2003-2010.
2. Potential and Actual Evapotranspiration has been estimated, for major crops in 16 blocks of region I and for 4 blocks of region II.
3. Six different strategies are suggested and evaluated with special focus on conjunctive use of canal water with groundwater, and regulated deficit irrigation as applicable.
4. Water demand for groundwater and canal water has been estimated for normal, wet, and dry scenarios, according to type of monsoon.

6.4 Limitations of the Study

Local development of dual crop coefficient for various cultivars is a difficult task, as it requires measurements during the entire growth season. In absence of locally developed crop coefficients it is appropriate to use generalised values given in FAO - 56. Crop parameters used in this study are taken, either from FAO-56, or availed from local sources, which may which not be in sync with various cultivars used across the region. Thus, while accepting the crop coefficient values it should be borne in mind that generalized values could give errors in estimating crop evapotranspiration. It has been presumed that soil type across the block is homogeneous, but actually spatial variation is observed. The change in soil properties will have an impact on the inflows, and outflows in blocks, while estimating soil water balance. Due to varying soil distribution across the block, irrigation applied on the basis of percent of soil moisture status as per RAW/TAW is difficult to estimate across the block.

6.5 Scope for Future Work

1. Model can be integrated with groundwater model to investigate groundwater fluctuations.
2. Model can further be used for long term effect of climate change.
3. Model can be integrated with various crop growth models.
4. Model can be used to study hydropower generation and energy demands, pollution tracking, ecosystem requirements, and project benefit-cost analyses.
5. Model can be used for water balance accounting to study single sub-basins, or complex river systems to address issues such, as groundwater and stream flow simulations; water rights and allocation priorities; and matching supply and demand.
6. Model can help in assessing the future trends on effects of demand management on water systems under varied scenarios such as: population growth, groundwater fully exploited, introducing water conservation techniques, implementing efficient irrigation techniques, change in cropping pattern, change in agricultural crops, and effect of climate change on the hydrology.