CHAPTER 3

LITRETURE REVIEW

3.1 Introduction

Irrigation is the single largest user of water and it consumes over 70 percent of world’s supplies, through different well developed forms of water resources. To have food security in future, large investments are being made by Government of India. The proper management of water resource has become crucial, emphasizing on emerging need to evaluate an existing irrigation system.

This chapter summarizes the extensive literature review carried out for the present study problem. The important contribution of various researchers in application of Remote sensing tool along with Geographical Information System (G.I.S) for evaluation various performance diagnosis parameters within different irrigation command areas.

1) Land use/Land cover classification

2) Evaluation of performance indices like Equity, Adequacy and Agriculture water productivity from Remote sensing based vegetation indices like Normalized Difference Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) and other remote sensing principles like surface energy balance(SEBAL) algorithms, Soil moisture assessments etc.

3) Generate the Crop Evapotranspiration (ETC) maps and thereby estimation of seasonal water demands of an irrigation command.

4) Identification of Potential Ground Water development sites within the study area.

5) Optimization of cropping pattern using judicious use of surface and ground water strategy.

3.2 Land use /Land cover classification

Anderson et al (1976) presented the framework of a national land use and land cover classification system for use with remote sensor data. The classification system has been developed to meet the needs of Federal and State agencies for an up-to-date overview of land use and land cover throughout the country on a basis that is uniform in categorization at the more generalized first and second levels and that will be receptive to data from satellite and aircraft remote sensors. The proposed system uses
the features of existing widely used classification systems that are amenable to data derived from remote sensing sources. It is intentionally left open-ended so that Federal, regional and local agencies can have more flexibility in developing more detailed land use classification at the third and fourth levels, in order to meet their particular needs and at the same time remain compatible with each other and the national system. Revision of land use classification system as presented in U.S. Geological Survey circular 671 was undertaken in order to incorporate the results of extensive testing and review of the categorization and definitions.

Settle and Brigs, (1987) assigned classes (training classes) verified on ground at selected areas. This training set represents a small percentage of an entire satellite image and because selection is made by field observers, sampling is often not random and is biased by few selection procedures. The maximum likelihood classifier is a successful criterion that is based on priori probabilities.

Unsupervised classification algorithm clusters pixels multispectrally into classes through the use of standard statistical approaches such as centroid and ward methods does not rely on classes assigned by field visits. Kiyonary et al.(1988) argued that unsupervised classification methods are better suited for classification of natural variations that are abrupt, clearly distinguished in spectral signatures. Hybrids of supervised and unsupervised classifications are often necessary to overcome the shortage of appropriate field data.

Chari et al (1994) studied the Bhadra irrigation project of Karnataka; using IRS P6 WIFS, multirate satellite data prior to and after implementation of National Water Management Project (NWMP). They provided the spatial information on irrigated area and estimated productivity of paddy upto distributory level.

Soil moisture assessment for developing adequate water supply zones was identified by Engman & Chauhan (1995) using Microwave techniques.

A particular phenomenon in pixel-based classification is “mixed” pixel, which comprises of heterogeneous land surface, i.e., two or more objects occur within a single pixel. In agricultural areas, crop variety, seeding dated and supply of fertilizer are often unevenly distributed among and within farm fields. Leguizamon et al. 1996 attributes to wide scatter of spectral reflectance of a given crop. Fuzzy classification, with more continuous land cover classification classes have been invented to account for variations in natural conditions. Fuzzy classification are based on the relative strength of a class membership that a pixel has relative to all defined classes; and
fuzzy classification requires no assumption about statistical distribution of the data. The degree of membership within fuzzy set is a scaled number between 0 and 1. More information on fuzzy classifier is given in Zimmerman, (1991). For more thematically discern land use and crop classes, neural network classifier is also existing.

WIM G.M. Bastiaanssen, (2000) clearly states in his book, that supervised classification approach is the most common methodology for forming classes that are similar in spectral reflectances.

V. S. Brahmbhatt et al (2000) studied the temporal changes (1988-89 to 1997) in land use/land cover using multi temporal satellite data in Mahi Right Bank main canal command area in Kheda district of Gujarat state. By utilizing the images they concluded that command area is affected by water logging and salinity. Land use/Land cover change is maximum in a distributory (Lambhvel) situated in highly urbanized zone of Anand city, where built up area increased from 281 ha. to 460 ha. Salt affected area has increased in Chikhaliya command and decreased in Manej command. Water logging is maximum in Pansora command area with 586 ha. of water logged area in 1997.

Anita K. Prakash et al (2007) decided alternative sustainable landuse pattern of Ranga Reddy district, Yacharam Mandal of Andhra Pradesh. Land Use Land Cover maps were digitized for the study area and based on various land cover classes sustainable water shed development was suggested by giving priority to agriculture first and also working for soil and water conservation practices, ground water prospects, land capabilities.

3.3 Evaluation of performance indices for an Irrigation Command

Adequacy, equity and agricultural productivity were worked out by various researchers using different remote sensing principles. Jackson et al (1981) studied Crop water stress index by temporal soil moisture studies during the growing period using surface energy balance principle (SEBAL Model).

Abernethy and Pearce (1987) clearly state that Performance evaluation is considered to be one of the most essential elements for improving irrigation management. It is significant to quantify the existing according to ideal system and also benchmarking the various parameters involved in quantifying the system performances at different levels.
Menenti et al. 1989 evaluated crop water requirements by estimation of evapotranspiration $E_{TC}$ component using energy balance techniques (SEBAL, Model). The SEBAL model, developed by World Water Watch company, estimates the crop evapotranspiration as the “residual” of energy balance, by an equation $ETc = (Rn - G - H)$, $Rn$ is the net radiant energy exchange at the earth's surface, called net radiation; $ETc$ = the evapotranspiration expressed as latent heat flux density; $H$ = the net surface atmosphere flux of sensible heat; $G$ = the soil heat flux density. In the term $Rn$, all possible sources of radiation energy are considered and rest is all consumers of energy.

Agricultural productivity was found by Menenti et al. (1989) from actual evapotranspiration over water applied by water balance principle of remote sensing. Evapotranspiration maps were evaluated applying water balance algorithms and values were divided by values of water applied.

Menenti et al. (1989) found out water application per unit area from vegetation indices, this clearly indicated the equity of the water distribution system.

Adequacy of an irrigation system describes to what extent is the quantity of water provided sufficient for the growth needs of the crops Abernethy, (1989).

Performance evaluation terms quantify how much system is closer to the ideal irrigation system. Based on a review of the literature concerning, indicators of irrigation performance, Rao (1993) found that the performance of an irrigation system could be evaluated in three categories, namely, water delivery system, irrigated agriculture system and irrigated agricultural economic system.

Water deficit index (WDI) was developed to indicate the crop water deficiency by Moran et al. (1994).

Crop water requirement was worked out by Bastiaanssen et al. (1996) as indicator of crop water stress using SEBAL model (Surface Energy Balance Algorithms) based on surface energy balance techniques.

Bastiaanssen et al (1996) worked out coefficient of variation of evapotranspiration as well as coefficient of variation of evaporative fraction estimated using surface energy balance techniques and found out the equity of the irrigation system.

Successful irrigation scheme is the one that can apply the right amount of water over the entire region of interest without loss Zerihun et al., (1997). This is possible only if growth stages are accurately monitored.
Thiruvengadachari and Shaktivadvel (1997) found the vegetation index for cropped area and divided the values by water applied to find the agricultural productivity. The productivity was in the terms of ratio

Various workers have used remote sensing (RS) as a tool for assessment of irrigation performance. Bastiaanssen (1998) has listed the performance indicators derived from RS algorithms supplemented by ground data.

C.J.Perry (1999) concluded that the traditional analysis of irrigation performance, especially the concept of irrigation efficiency, can mislead planners and a policy maker especially of water availability at the river basin level becomes the primary constraint to agricultural production. Improving the productivity of water, not land requires rethinking of some basic facts about irrigation performance new way of managing and may be contradictory to some recent trends.

Bastiaanssen et al.1999a evaluated spatial geometry of crop yield from vegetation index to comment on equity as part of performance evaluation of Sirsa irrigation circle. The command areas of different distributaries, under consideration were divided in three different parts considering head to tail category and the crop vigor was evaluated from head to tail reach of distributory, to comment on equity of the system.

Bastiaanssen et al (1999b) evaluated the productivity of agricultural land by estimation of crop yield using Vegetation indices and then taking it’s ratio over evapotranspiration. The evapotranspiration for this work was found out using surface energy balance technique.

The relative water supply (RWS), evaluated by Ray and Dadhwal (2000) describes the adequacy of water supply. They worked out RWS for which Irrigation requirement was worked out using the evapotranspiration value derived from vegetation indices.

Hong-Yong Sun et al (2006) conducted experiments during different growing stages of winter wheat (Triticum aestivum L.) at Luancheng agro-ecology systems station of the Chinese Academy of Sciences during 1999/2000, 2000/2001 and 2001/2002 to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between seasonal amounts of irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield in the NCP, 300mm is an optimal amount of
irrigation, corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

A.V. Sureshbabu et al (2007) evaluated the water utilization index (WUI) defined as area irrigated per unit volume. WUI becomes measure of water delivery performance and constitutes one of the major performance indicator of irrigation system. In the study carried out the author used WUI and inverse of WUI, adequacy as the performances for benchmarking the performance of Nagarjunasagar Left bank canal command (NSLC). Optimized temporal satellite data of Rabi season during the years 1990-91 and 1998-99 was used in deriving irrigated crop areas adopting hierarchical classification approach. Paddy being the predominant crop equivalent wet area for (paddy crop area) was found using operational project specific conversion factor. The WUI was found at disaggregated levels viz, distributory, irrigation block, irrigation zone level.

Tzai-Hung Wen et al (2007) utilized regional irrigation water-demand planning to establish appropriate cropping patterns and estimate irrigation water demand. Although optimization methods have been extensively adopted, uncertainties of meteorological conditions and the complexity of spatial contexts make developing explicit and structured decision making extremely difficult. Rather than generating a single optimal solution, decision makers have preferred to generate several possible scenarios and compare results. This study proposes a novel spatial scenario based planning framework, with a database, model base, and scenario-setting modules, to generate flexible spatial planning scenarios for improving irrigation water-demand planning. A prototype of the proposed scenario-based framework is implemented on a geographic information system platform to assist in spatial decision making. Demand planning during a drought period for the Chia-Nan irrigation command area, the largest one in Taiwan, is adopted as a case study to demonstrate the proposed framework for spatial scenario analysis.

J.O. Payero et al (2009) in their study evaluated the effect of timing of a deficit-irrigation allocation (150 mm) on crop evapotranspiration (ETc), yield, water use efficiency (WUE = yield/ETc), irrigation water use efficiency (IWUE = yield/irrigation), and dry mass (DM) of corn (Zea mays L.) irrigated with subsurface
drip irrigation in the semiarid climate of North Platte, NE. During 2005 and 2006, a total of sixteen irrigation treatments (eight each year) were evaluated, which received different percentages of the water allocation during July, August, and September. During both years, all treatments resulted in no crop stress during the vegetative period and stress during the reproductive stages, which affected ETc, DM, yield, WUE and IWUE. Among treatments, ETc varied by 7.2 and 18.8%; yield by 17 and 33%; WUE by 12 and 22%, and IWUE by 18 and 33% in 2005 and 2006, respectively. Yield and WUE both increased linearly with ETc and with ETc/ETp (ETp = seasonal ETc with no water stress), and WUE increased linearly with yield. The yield response factor (ky) averaged 1.50 over the two seasons. Irrigation timing affected the DM of the plant, grain, and cob, but not that of the stover. It also affected the percent of DM partitioned to the grain (harvest index), which increased linearly with ETc and averaged 56.2% over the two seasons, but did not affect the percent allocated to the cob or stover. Irrigation applied in July had the highest positive coefficient of determination (R2) with yield. This high positive correlation decreased considerably for irrigation applied in August, and became negative for irrigation applied in September. The best positive correlation between the soil water deficit factor (Ks) and yield occurred during weeks 12–14 from crop emergence, during the ‘‘milk’’ and ‘‘dough’’ growth stages. Yield was poorly correlated to stress during weeks 15 and 16, and the correlation became negative after week 17. Dividing the 150 mm allocation of water, about evenly among July, August and September was a good strategy resulting in the highest yields in 2005, but not in 2006. Applying a larger proportion of the allocation in July was a good strategy during both years, and the opposite resulted when applying a large proportion of the allocation in September. The different results obtained between years indicate that flexible irrigation scheduling techniques should be adopted, rather than relying on fixed timing strategies.

Frequency and depth of irrigation play crucial role in crop yield and use efficiency of water resource. To test this hypothesis a field study was carried out by S.Sarkaran et al (2009) in November to January of 2001–2002 to 2003–2004 on a sandy loam (Aeric haplaquept) for quantifying the frequency and depth of irrigation on growth, curd yield (CY) and water use pattern of cauliflower (Brassica oleracea L. var. botrytis). Four irrigation frequencies depending on the attainment of cumulative pan evaporation (CPE) values of: 25 (CPE25), 31(CPE31), 38 (CPE38) and 45
(CPE45) mm were placed in main-plots, with three depth of irrigation (IW) of 35 (IW35), 30 (IW30) and 25 (IW25) mm in sub-plots. Water use efficiency (WUE), net evapotranspiration efficiency (WUEET) and irrigation water use efficiency (WUEI) were computed. Marginal water use efficiency (MWUE) and elasticity of water productivity (EWP) were calculated using the relationship between CY and seasonal actual evapotranspiration (SET). A continuous increasing trend in growth parameters, yield and WUEI was recorded with the increase in SET from CPE45–IW25 to CPE31–IW30. However with further increase in SET the same decreased up to CPE25–IW35 regime. Highest WUE and WUEET obtained under CPE38–IW35 regime where SET value was 5% lower than the status of SET under CPE31–IW30. This study confirmed that critical levels of SET needed to obtain maximum curd yield or WUE, could be obtained more precisely from the knowledge of MWUE and EWP.

3.4 Identification of Potential Ground Water development sites within the Study area.

Saraf et al (1998) used integrated IS and remote sensing approach for identifying ground water prospective sites within the Silai watershed of Bankura district, West Bengal and thereby selecting recharge sites and identifying future recharge sites. IRS LISS-II and LISS-III data have been used with other collateral data to develop thematic object classes, integration of thematic classes is done using RS and GIS tool. Weighted Index overlay method is used for delineation of prospective ground water sites.

Obi et al (2000) explored at Gaimukh watershed that lineaments play important role in storing ground water specially the rocky terrain. Ground water potentiality of such places where the intersection of two lineaments takes place is more positively existing. This can’t be applied on flat Terrain as of North Gujarat.

Bahuguna et al (2003) highlighted that lineaments plays important role in water potentiality of the landform. Mapping of lineaments using remote sensing data is very common practice for preliminary delineation of the ground water prospective zones.

Murthy et al (2003) demonstrated at RS combined with GIS have been proved to be very efficient in identification of ground water. Various thematic maps are assigned weights and on the basis of infiltration capacity of each zone the potential zones are delineated.

Ground Water Quality Zonation in Nakrekal Basin, Nalgonda District, Andhra Pradesh, India. In this study, water quality parameters (pH, TDS and F) available at
different well locations in the study area have been collected, compiled, and digitized and analyzed in the GIS environment to carry out quality zonation for drinking water purpose (Kumar and Anjaneyulu 2003). In order to know the spatial distribution of these quality parameters, inverse distance weighted method was used to interpolate the point values using Arc View GIS software followed by reclassification of the interpolated maps (potable and nonpotable) as per the guidelines prescribed by the Bureau of Indian Standards. Further, these classified quality parameter maps were recoded and integrated using GIS to prepare a quality zonation map which provided the following information: (1) spatial distribution of safe (potable) and un-safe (non-potable) ground water quality areas, and (2) parameter responsible for non-potability in each non-potable zone Vulnerability Assessment Of Coastal Water Pollution Due To Salt Water Ingress In A Low Lying Coastal Flats. Vulnerability assessment of aquifers to salt water intrusion has been carried out in Bhavnagar District, Gujarat using GALDIT index (similar to DRASTIC index) (Mitra 2005). The method used and the results obtained are summarized here. The acronym GALDIT is formed from the following highlighted letters of the most important mappable factors that control the seawater intrusion:

1. Groundwater Occurrence (aquifer type; unconfined, confined and leaky confined).
3. Depth to Groundwater Level above Sea.
4. Distance from the Shore (distance inland perpendicular from shoreline).
5. Impact of existing status of seawater intrusion in the area.
6. Thickness of the aquifer, which is being mapped.

Each GALDIT factor has been evaluated with respect to the other to determine the relative importance of each factor and has been assigned a relative weight of 1 (least significant) to 4 (most significant). A rating value between 1 and 10 to each parameter (within each factor) has been assigned, depending on local conditions. The aquifer Vulnerability index to seawater intrusion is then obtained by the following expression:

\[ \text{GALDIT} = 1 \times G + 3 \times A + 4 \times L + 2 \times D + 1 \times I + 2 \times T \]

Where 1, 3, 4, 2, 1, 1 are weights assigned to each controlling factor of GALDIT. Once the GALDIT index has been computed, it is possible to identify areas, which are more likely to be susceptible to seawater intrusion relative to one another. The higher
the index, greater the seawater intrusion potential. Figure 6 shows the vulnerability zonation around Bhavnagar district in pre- and post-monsoon periods, respectively. It is important to note that the GALDIT index provides only a relative tool and is not designed to provide absolute answers.

Shakthivel et al delineated the ground water potential zone for Kalrayan hills, in Tamilandu. The study was done using IRS-1C FCC data and with aid of visual image interpretation various thematic maps were generated and integrated using GIS software. The study concluded that lineaments, fractured zones and valley fills with buried pediments are prospective ground water zones.

Jagadeeswara et al (2004) used satellite remote sensing data to define the spatial distribution of different ground water prospect classes. Analysis of ground water prospective zones can be done using high resolution satellite imagery, SOI, Survey of India toposheet and collateral data with enough ground truthing can be of great use. Dissanayake et al (2005) carried out the remote sensing based exploration at Giri river watershed spreaded over Sirmur, Solan and Shimla of Himachal Pradesh, India. They adopted the weighted index overlay method. The thematic layers were prepared using IRS-P6 LISSIII and LANDSAT 7 ETM data along with Survey of India toposheet, existing maps and field observation data have been used to extract the hydrogeomorphic features of this hard rock terrain.

Nag et al (2005) overlaid the hydrogeometric unit over the lineament maps to delineate the water prospective zones. The weighted overlay technique was used.

Ravi et al (2005) attempted to identify zones favorable for the application and adaptation of site specific artificial recharge techniques for augmentation of ground water through a Geographic information system (GIS) based hydromorphic approach in the Bhatia and Kalu river basins of Thane district. The hydrogeomorphological information of both basins extracted from IRS 1C LISS-III data supported by information on drainage pattern, DEM derived slope, lineament density, drainage density and ground water conditions prevailing. The integrated study helps to design suitable ground water management strategies.

Anita K. Prakash et al (2007) decided alternative sustainable landuse pattern of Ranga Reddy district, Yacharam Mandal of Andhra Pradesh and also based on integration various thematic maps using GIS identified the ground water prospective zones thereby attaining the goal of developing sustainable water shed development program.
Gurugnanam et al (2008) developed the hydro-geo-morphological map with spatial distribution of its elements through GIS system. The thematic maps of Geology, geomorphology and lineaments were prepared using ERDAS Imagine and ArcGIS. These thematic maps were integrated to synthesize the hydrogeomorphological map with GIS Software.

M.Girish Kumar et al (2008) delineated potential harvesting sites using RS & GIS using the using LISS III data and survey of India (SOI) and other collateral data. Various thematic maps were generated using the principles of thematic class reflectance and potentiality of groundwater depending on it’s water storing capacity. Each class was given the rank and the class or theme was given the weightage and they were reclassified for the suitability of water bearing potential. All reclassified maps were further integrated using GIS and potential ground water potential maps were prepared.

Saumitra Mukherjee et al (2008) revealed in their paper Spatial as well as spectral resolution has a very important role to play in water resource management. They explored the groundwater and rainwater harvesting sites in the Aravalli Quartzite-Granite-Pegmatite Precambrian terrain of Delhi, India. Use of only panchromatic sensor data of IRS-1D satellite with 5.8-meter spatial resolution has the potential to infer lineaments and faults in this hard rock area. It is essential to identify the location of interconnected lineaments below buried pediment plains in the hard rock area for targeting sub-surface water resources. Linear Image Self Scanning sensor data of the same satellite with 23.5-meter resolution when merged with the panchromatic data has produced very good results in delineation of interconnected lineaments over buried pediment plains as vegetation anomaly. These specific locations of vegetation anomaly were detected as dark red patches in various hard rock areas of Delhi. Field investigation was carried out on these patches by resistivity and magnetic survey in parts of Jawaharlal Nehru University (JNU), Indira Gandhi national Open University, Research and Referral Hospital and Humayuns Tomb areas. Drilling was carried out in four locations of JNU that proved to be the most potential site with ground water discharge ranging from 20,000 to 30,000 liters per hour with 2 to 4 meters draw down. Further the impact of urbanization on groundwater recharging in the terrain was studied by generating Normalized difference Vegetation Index (NDVI) map which was possible to generate by using the LISS-III sensor of IRS-1D.
satellite. Selection of suitable sensors has definitely a cutting edge on natural resource exploration and management including groundwater.

G. N. Pradeep Kumar et al (2010) used powerful and high speed personal computers, efficient techniques for water management have evolved, of which Remote Sensing and GIS are of great significance. Groundwater resources potential has been evaluated in Kurmapalli Vagu basin using Remote Sensing and GIS techniques. With the help of Survey of India toposheets and satellite data, various thematic maps like base map, drainage map, geology map, geomorphology map, slope map, drainage density map and land use / land cover map of the study area have been prepared using Arc GIS software. These thematic maps have been integrated and appropriate weightage have been assigned to various factors controlling occurrence of groundwater. The results show that there are five categories of groundwater potential zones ranging from very good to poor. The categorization of groundwater potential zones is in general agreement with the acquired yield data of the existing dug wells and bore wells. This depicts the favorable potential zones in the study area for evaluation of groundwater resources. Finally it is concluded that the Remote sensing and GIS techniques are very efficient and useful for the demarcation of groundwater potential zones.

Weerasinghe et al (2010) described a comprehensive and convenient method to optimize the locations to implement integrated water management strategies efficiently and effectively. To illustrate this routine methodology, they developed a spatially explicit spatial analysis model: Geographic Water Management Potential (GWAMP). The focus was on the aspect of using GIS, to find adaptation- and mitigation- strategic solutions for water management, by applying GWAMP at global scale. Since these solutions are important towards ensuring- and improving- agricultural land productivity at climate initiated water related drastic events. They retrieved input data from global data repositories and rescaled to 1km spatial resolution, to obtain a set of manageable input data having adequate level of information. Potential runoff was calculated as an intermediate input using the Soil Conservation Service Curve Number (SCS-CN) equation. Multi Criteria Evaluation techniques are used in decision making, in order to analyze the results reflected by specific suitability levels and relative importance of input parameters. Accordingly, the model specifies potential water harvesting- and storage sites for on-farm water storage, regional dams, and soil moisture conservation.
3.5 Generate the Spatial Crop Evapotranspiration (ETC) maps and thereby estimation of seasonal water demand for irrigation scheduling.

An accurate estimate of the evapotranspiration (ET) and crop water productivity (CWP) at regional scale is a thrust area of research focus and must be a key to the practice of water-saving in agriculture irrigation in most water stressed areas of the world. A state of art review in the area is presented below.

Landsat satellite Thematic Mapper (TM) data were explored by Sun F. Shih et al. (1993) as an alternative for monitoring regional soil moisture conditions, the theoretical method of using single daily temperature data sets to estimate root zone soil moisture was tested with ground-based observations. Results indicated that the percentage gravimetric soil moisture content in the 0-24-cm depth was inversely related to the soil surface temperature. A demonstration of Landsat-TM based soil moisture estimation was performed for Lee County in southwestern Florida. The thermal infrared (IR) data from TM band 6 were overlain onto four principal land-use categories (agricultural/irrigated, urban/clearings, forest/wetlands, water) using a geographic information system (GIS). The thermal-IR data were used to assess four qualitative soil moisture conditions (water/very wet, wet, moist, and dry) within each land-use category. Integration of Landsat thermal-IR data with land-use through GIS under certain conditions may be a useful technique for assessing regional soil moisture conditions, and further research to refine and quantify this technique is recommended.

Ray et al. (2000) used remote sensing and Geographic information system (GIS) for estimating seasonal crop evapotranspiration (ETC) in Mahi Right Bank Main Canal (MRBC) of Gujarat state of India. Crop coefficients (Kc) for various major crops growing in the command of MRBC were estimated empirically using Soil adjusted vegetation index (SAVI) values. Reference crop evapotranspiration (ET0) maps were generated using point meteorological values. The (ET0) and (Kc) maps were combined to generate the seasonal crop evapotranspiration (ETC) map which highlighted spatial variation in (ETC).

Limited precipitation restricts yield of winter wheat grown in the North China Plain (NCP). Hong-Yong Sun et al. (2006) conducted Irrigation experiments during different growing stages of winter wheat (Triticum aestivum L.) at Luancheng agro-ecology systems station of the Chinese Academy of Sciences during 1999/2000,
2000/2001 and 2001/2002 to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between seasonal amounts of irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield in the NCP, 300mm is an optimal amount of irrigation, corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

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Ahmed et al (2008) used the method to compute the ET and CWP using the remote sensing data for Bari Doab province in Pakistan. The daily ET can be calculated using SEBAL model with NOAA remote sensing data in some non-cloud days whereas the reference daily crop ET can be estimated using meteorological data based on Hargreaves es approach. The daily ET and the total ET over the entire growing season of winter wheat were obtained using crop coefficient interpolation approach. The calculated average and maximum water consumption of crops can be used respectively. The calculated daily ET from SEBAL model shows good match
with the observed data collected in a Lysimeter. The error of $E_T$ estimation over the entire growing stage of winter wheat was approximately 4.3%. We can observe a close linear relationship between CWP and yield. We also observed that the continuing increase of $E_T$ leads to a peaking and subsequent decline of CWP, which suggests that the higher water consumption does not necessarily lead to a higher yield.

The Global Environment Fund (GEF) project on Integrated Water and Environment Planning and Management presents a new approach to the chronically water short region and to the receiving environment of the Bohai Sea. The root cause of ecological decline in the shallow semi-enclosed Bohai Sea is the uncontrolled pollutant discharges from the main tributaries to the Bohai Sea and the reduction in total volume of freshwater reaching the Sea. The Hai River Basin is one of the seven river basins that flow into the Bohai Sea. A key element in the project is the establishment of real water savings program through an $E_T$ reduction strategy, which will enhance the stream flow and freshwater discharges into the Bohai Sea. The objective of this remote sensing project is to generate the spatially distributed values of actual $E_T$, biomass production and soil moisture. Data from the MODeorate resolution Imaging Spectroradiometer (MODIS) satellite has been used to estimate the land surface energy balance at basin scale with use of SEBAL. The large MODIS swath width of 2330 km and its daily repetitive image acquisition is suitable to cover large river basins such as the Hai Basin. The Landsat swath width is 185 km and it has pixel dimensions of 30 m which is not suitable to cover the Hai Basin. Landsat images have therefore only been used to survey the 15 counties that were selected for demonstrating local solutions to $E_T$ reductions www.waterwatch.nl.

Reliable estimates of evapotranspiration $ET$ from vegetation are needed for many types of water-resource investigations. How well models can estimate ET from vegetation varies, depending on the capabilities of the model as well as the nature of the targeted vegetation. Model accuracy also depends heavily on the quality and quantity of the data used. Several ET models have been developed that use an energy balance approach in which the data used by the models are derived from satellite imagery. Ayman Elhaddad et al 2008 in their research introduced an enhanced surface energy balance-based model, the remote sensing of evapotranspiration or ReSET model, for estimating ET. ReSET is an ET estimation model that takes into consideration the spatial variability in weather parameters, which makes it particularly applicable for calculating regional scale ET. ReSET also has the capability of
interpolating between the available weather stations in time and space. The model’s accuracy at daily and seasonal time scales is evaluated in several case studies.

N. K. Lenka et al (2008) have attempted to study the possibility to enhance the utility of soil–plant–atmosphere–water SPAW model that has been used successfully by various workers in different countries for soil moisture prediction under different cropping conditions. One of the major climatic inputs for SPAW model is pan evaporation, which in many places is not readily available. To address the above, and to get the benefit of this model in regions characterized by limited weather data availability, this study was undertaken using computed E\textsubscript{T0} from air temperature by the 1985 Hargreaves equation, as one of the inputs in place of pan evaporation. For the purpose, actual air temperatures collected from experimental farm area, as well as forecast air temperature collected from National Centre for Medium Range Weather Forecasting, Government of India, were used. First, the SPAW model was calibrated and its performance was evaluated under wheat, taking layer wise and profile soil moisture as the variables for comparison between the predicted and observed values. The results showed that the root-mean-square error (RMSE) varied from 0.30 to 0.58 cm for measured values ranging between 2.24 and 4.25 cm. The index of agreement (d) varied from 0.81 to 0.92 and coefficient of determination (r\textsuperscript{2}) from 0.46 to 0.73 for 0–15, 15–30, 30–45, and 45–60 cm soil depths. For the whole 60 cm profile, the RMSE was 1.07 cm with d and r\textsuperscript{2} values of 0.94 and 0.85 respectively. The RMSE and varied from 0.36 to 0.63 cm and 0.77 to 0.89 respectively when E\textsubscript{T0} computed from actual air temperature was used in place of pan evaporation, whereas when E\textsubscript{T0} computed from forecast air temperature data was used, the corresponding values were 0.35–0.64 cm and 0.68–0.85 respectively for the four soil layers. There was a tendency of the models to underestimate when the computed E\textsubscript{T0} was used as input in place of pan evaporation. In general, performances of the models were better at lower depths.

M.D. Ahmad et al (2008) used the energy balance techniques using remote sensing data, directly to estimate actual crop evapotranspiration, i.e. water consumption in Rechna Doab irrigation system of Pakistan. The study evaluates remote sensing based water consumption and water stress areas, which was combined with secondary agricultural production data to give estimates of irrigation performance, including water productivity, at a variety of scales than alternative
options. Remote sensing based indicators reflecting equity, adequacy, reliability and water productivity were estimated.

3.6 Optimization of cropping pattern Judicious use of surface and Ground water.

Smith (1970) has studied conjunctive surface and development from tube wells to determine the optimal capacities for canal and ground water development maintaining specified water development, maintaining specified water balance and endogenously determine optimal cropping patterns

Morel-Seytoux (1980-1981), developed special distributed parameter surface ground water models for stream aquifer management. These models use a technique referred to as the “discrete Kernel approach” of ground water modeling. This technique is based on the classical Green’s function method of solution of partial differential equations stream aquifer simulation model based on the discrete Kernel approach was developed to evaluate different conjunctive use management strategies in the South plate river in Colorado.

Chaube (1984) used the deterministic linear programming models to evaluate impact of conjunctive use of surface and ground water on irrigation policy in the commands of major surface water supply project in Gandak, Kosi & Sonsub basins. The models were used to analyze irrigation development in each of three major distributory subsystems under three conditions namely; a) when on surface water was used for irrigation water supply b) when surface and ground water were used conjunctively) When Kharif channels are used to artificially recharge the aquifers.

Radhey Shyam (1985) presented a linear programming model with an objective function to maximize the aggregated annual return from an area. An optimal cropping pattern, matching the available land and water supplies, against socio economic constraints has been recommended. Three tube well water supply levels with two canal water levels have been considered. Increase in irrigation water supply levels in general during peek demand periods in particular results in increase in total return of the area selected for study.

Cheiw et al (1995) described a technical & feasibility study of increasing ground water usage to supplement surface water use in the campaspe valley in south-western Australia. An integrated model which simulates the surface and ground water process, as well as interactions between the processes, is used to determine the
sustainable long term ground water pumping yields. The model also provides estimates of ground water fluxes for various movement options of increasing ground water usage.

Conjunctive use studies conducted using techniques of operation and research have been reported by Sahuquillo A, Lluria, (2003), concluded in their studies that conjunctive use is potential solution for stressed aquifers: social constraints He also reviewed literature and published the conclusions of various researchers.

Ishtiaq Hassan et al (2004) applied Linear Programming Model to calculate the crop acreage, production and income of the Faisalabad division. The study was conducted on 2702 thousand acres of the irrigated areas from the three districts. Crop included in the model were wheat, Basmati rice, IRRI rice, cotton, sugar cane, maize and potato. The results showed that the cotton, maize and wheat gained acreage by about 5-10%, while main losers were Basmati rice, IRRI rice, sugarcane and potato. Overall optimal crop acreage increased by 1.88% while, optimal income was increased by around 2% as compared to the existing solutions.

Dr.V.Jyotiprakash (2006) decided optimal cropping pattern of Sri Ram Sagar reservoir project system in Andhra Pradesh, India. A stochastic linear programming model has been developed to determine the optimal cropping pattern and optimal operational strategies under different dependable inflow levels. The optimal operational strategies derived from the model can be expressed as a rule curve to provide guidelines for the operator of the reservoir system under different condition of inflows.

N Vivekanandan, (2008) carried out the studies on optimization of cropping pattern with available land and water, essentially carried out under a set of limitations to maximize the crop production to satisfy increasing population and to achieve the maximum net return for the project. The study presents that linear and goal programming (LP and GP) approaches which were adopted for optimization of cropping pattern with available land and water for maximization of net return for upper Indravati irrigation project. Factors like net return, total cropping intensity and average water utilized by cropping patterns of LP and GP were considered for the selection of best cropping pattern for maximization of crop production and net return. It was concluded that the cropping pattern of GP was found to be the best and gave maximum net return for this project under study.
3.7 Books and Manuals cited:


