WATER RESOURCES MANAGEMENT AND CROP-WATER REQUIREMENT IN ARID AND SEMI ARID REGIONS OF PAKISTAN

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ABSTRACT
The study has focused on the effective and rational utilization of water resources in arid and semi arid areas of Pakistan. The crop water requirements with respect to water sources availability have been analyzed. A case specific study approach was adopted which was kept limited to district boundaries so that the local government and other organizational structure may implement the recommendations and results of this study. Data regarding agriculture statistics, rainfall, evaporation, cropping patteren and other relevant parameters for the area under study was collected from Meteorological Department of Pakistan, Pakistan Council for Research in Water Resources, National Agriculture Research Council Islamabad, Pakistan, Arid Agriculture University Rawalpindi, Pakistan, Water Gate Way Pakistan Website, Federal Bureau of Statistics and Ministry of Food Agriculture and Live Stock. CropWat software was used to estimate the crop water requirements. It is observed that crop water requirements of most of the crops are not met with the average rain and need an additional source of water both in Gawadar and Zhob areas.

Introduction
Sustainable water resources development is becoming highly important world wide. More than one third of the earth's land surface is arid where the process of land degradation has intensified in recent decades causing desertification. About 14 percent of the total area of Pakistan is under main deserts namely Thar, Cholistan, Thal, Kharan and Chagai. On the whole more than half the country receives less than 205 mm of annual rainfall. The mean annual precipitation ranges from less than 100 mm in parts of the Lower Indus Plain to over 750 mm near the foothills in the Upper Indus Plain. The other main source is groundwater. However groundwater in most part of the area under study is saline. When there is no rain in these deserts for long period it causes drought and people are compelled for migration along with their livestock. As a result of drought, grazing lands are reduced or abolished which cause increase in livestock mortality and add untold miseries to human beings (Kahlown 2002 [1])

Twenty three districts in Balochistan, Thar, Dadu and Thatta in Sindh, and Cholistan in Punjab are usually hit by the drought. Its impacts are reflected all over the country. Famine-like situation is faced in the severely affected areas resulting in migration of millions of families to 'safe areas', hundreds of people have lost their lives and countless livestock have died due to lack of water and grass. The cycle of drought does not seem to be ending. The amount of rainfall has been consistently decreasing over the last few years. It is feared that its effect may prolong causing more devastating situation in the country.

The problem of water scarcity in Pakistan does not solely stem from a shortage of resources. Its roots also lie in the realm of awareness and willingness to find a participatory solution that is feasible and sustainable. In this regard one of the key parameter which should be known before hand is the crop water requirements. The present study has addressed evaluation of this parameter. There is extensive work on methods to estimate the crop water requirements (Hargreaves and Zohrab (1985) [2], Ullah et al., (2001) [3], Bastiaanssen and Chandrapala (2003) [4], Bastiaanssen et al. (2005) [5], Allen et al., (2005) [6], Kuo et al., (2006) [7], Laghari et al., (2008) [8] and Shakir et al (2010) [9] . Penman–Monteith equation has commonly been used by many researchers. FAO favors a standardized grass of 12 cm height and ASCE has recommended one short crop (grass) and a tall crop (alfalfa) as the reference crops. Although use of the above two methods in various parts of the world is cited (Allen et al., 2005 [6]), only a couple of studies (Ullah et al., 2001 [3]; Laghari et al., 2008) [8]) are found for the Pakistan region employing this scientific method for estimating evapotranspiration and thus crop water requirement. Laghari et al.'s (2008) [8] study does not cover a whole canal system but rather is limited to a few wheat fields, while Ullah et al. (2001) [3] estimated crop water requirements for the whole of the Indus Basin irrigation system. Ullah et al. (2001) [3],

however, fell short of estimating the irrigation demands and comparing the estimated irrigation demands with the actual supplies. The present study will fill this gap of estimating the crop water requirement based on the ASCE standardized Penman–Monteith (2000) [10] equation, converting it to irrigation demands and then comparing it with the actual water supply to obtain an insight into possible improvement of a canal irrigation system in Pakistan.

Evaluation of Crop Water Requirements (CWR) Using CropWAT for Windows

CropWat for Windows Software has been used to assess crop sustainability through evaluation of CWR for the case study areas. It is very useful software for irrigation planning and management which can be used to evaluate rain fed production and drought effects as well as the efficiency of the irrigation practices.

Methodology

The methodology developed in this study followed the case study approach to assess impacts of drought and to find out sustainable water resource management techniques. Climatic and agriculture data have been used to run models to analyze water resource management and irrigation practices in vogue with an emphasis on need of adopting such crop patterns as are more sustainable for a certain agro-climatic zone.

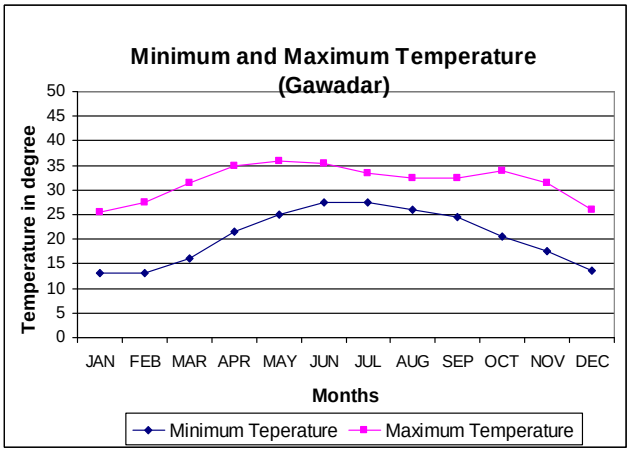
A water a balance approach has been used to determine the effect of the drought on irrigation water budget. This approach first quantifies the variations in water supply (with prime consideration of rainfall for rain fed areas). Secondly the responses of the consumptive use are quantified using a consumptive use model which utilizes climate and plant parameters to estimate the crop consumptive use as well as irrigation water requirement for different crops for the study area. The major considerations for the selection of the area for case study are the availability of, accuracy and adequacy of the data for the modeling and validation processes. Such considerations eventually lead to selection of two case studies from Balochistan Districts of Gawadar and Zhob (worst hit by drought of 1999-2002). Data for the study area was collected from Ministry of Agriculture, Food and Livestock, (MINFAL) Islamabad, Pakistan (MINFAL 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003) [11], Nazir (1993) [12], Kahlown, (2002) [1] and Federal Bureau of Statistics (FBS), 2001) [13]

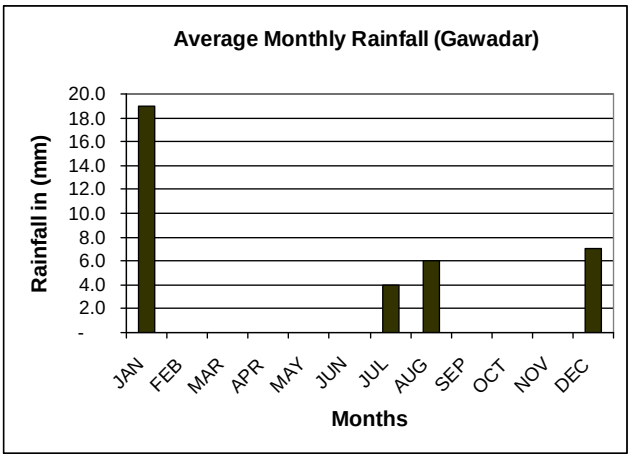
Case Study for Gawadar Area

Geography and Climate of the Area

The **Gawadar District**, lies at 0-300 meters above sea level, and its climate is dry arid hot. It is placed in "warm summer and mild winter" temperature region. The oceanic influence keeps the temperature lower than that in the interior in summer and higher in winter. Monthly temperature and rain is given in figure 1(a, b). The mean temperature in the hottest month (June) remains between 31^0 C and 32^0 C. The mean temperature in the coolest month (January) varies from 18^0 C to 19^0 C. The uniformity of temperature is a unique characteristic of the coastal region in Balochistan. Occasionally, winds moving down the Balochistan plateau bring brief cold spells, otherwise the winter is pleasant. In Gawadar, winter is shorter than summer. It stays only from December through February (3 months) while summer starts in March and prolongs up to November (9 months). Mean monthly temperature in summer remains between 21^0 C and 32^0 C. In the coldest month, January, the mean monthly temperature remains above 10^0 C. Freezing temperature has been recorded at Pasni but nowhere else in the district.

Aridity prevails all over the district because average annual rainfall is below 250 mm and in some years annual rainfall was even below 100 mm. Both the monsoons and the Western Depressions result in scanty rainfall but overall precipitation level remains low. According to the Pakistan Meteorological Department, total annual precipitation in 1994 was 159.1 mm at Pasni and 110.6 mm at Jiwani. (Pak MET)The extent of precipitation affects the supply of drinking water in Gawadar district as most of it is provided from reservoirs which are rain-dependent.





a) Monthly average of the minimum and maximum daily temperatures °C

b) Monthly average rainfall (mm)

Figure 1**:** Average Monthly Temperature and Rainfall at Gawadar

Classification of Land and Agriculture

In Gawadar district, agricultural land can be classified into irrigated and un-irrigated. Irrigated land has permanent sources of water like open surface wells or springs. There is not a single karez or kaurjo in the district. Un-irrigated land in Kulanch and Dasht valleys is rain-fed, locally called khushkaba, or flood irrigated (sailaba). Irrigated land is predominantly used for production of fruits however some crops are also cultivated in orchards. Crops like wheat, barley, and jowar are cultivated in un-irrigated land.

The Agriculture Department has sub-divided the net potential area available for cultivation into current fallow, net sown, area sown more than once and culturable waste. In Gawadar, about 97 percent of the area is either not yet reported or not available for cultivation. The arable land constitutes just one percent of the total area. The major reasons are scarcity of irrigation water and unavailability of agricultural labor.

Major Crops and Cropping Pattern

Major crops of the area are given in table 1. In Gawadar agricultural crops are categorized in two types, Rabi and Kharif, according to their cultivation seasons. Rabi crops are sown in winter and harvested in late winter or during early summer while Kharif crops are sown in summer and harvested in late summer or early winter. The major Rabi crops of the district include wheat, barley, muttar pulse, and various vegetables, but their current volume of production is comparatively negligible. Kharif crops in Gwadar district include mainly fruits and water melons, various vegetables and some jowar and mash. Fodder is cultivated throughout the year. Fruits are produced in Kharif season.

Dates, mangoes, fodder, water melons, citrus, tomatoes and wheat are the major agricultural produce of the area. Wheat is cultivated mostly in un-irrigated areas, rain-fed for the most part, while dates, other fruits, water melons, and vegetables are cultivated in irrigated lands. Although average per hectare yield of wheat in Gwadar (1,143 kg/Ha.) is not at par with the average yield of wheat for the province of Balochistan (2,320 kg/Ha.), it fulfils the local needs to some extent. Barley is another crop cultivated mostly in *khushkaba* lands.

Different vegetables and fodder are cultivated throughout the year. Date, the major produce among fruits, is most frequently planted on irrigated land. Dates require continuous irrigation and more care.

Table-1: Average Annual Production of Major Crops in Gawadar

Crops	**Area (Ha.)**	**Production (tones)**	**Yield (kg/Ha.)**
Fruits	2,496	20,997	8,412
Fodder	128	2,140	16,719
Water Melons	100	1,880	18,800
Vegetables	82	830	10,121

Wheat	70	80	1,143
Pulses	70	35	500
Barley	40	35	875
Jowar	30	25	833
Coriander	10	5	500
Bajra	9	5	556
Guar Seed	3	2	667
Total	3,038	26,034	

Irrigation Practices

The major source of irrigation in Gwadar is streams and springs etc. Other significant sources are tube wells, operated by diesel, and open surface wells from where water is taken out for irrigation with the help of diesel pumps. The remaining is *khushkaba* or *sailaba* land dependent upon rainfall. The total number of tube wells has decreased in *khushkaba* lands over the past years. It may be due to increase in the diesel price.

In flood irrigation, rain-water is harvested into the fields by embankment of fields. This provides enough water for cultivation of crops like wheat and barley. All the tube wells are diesel powered. These are used for irrigation in case diesel, illegally imported from Iran, is cheap. Otherwise tube wells are not operated and farmers wait for rainfall. Here it is necessary to clarify a misunderstanding, that the open surface wells with diesel pumps are often also called tube wells. In Pasni and Shadikaur area, there are 22 such open surface wells being used for irrigation.

Case Study for Zhob

Geography and Climate

The district lies between 30 ° 30¢ to 32 ° 05¢ north latitudes and 67 ° 26¢ to 70 ° 00¢ east longitudes. It is bounded on the north by Afghanistan and South Wazirestan agency of FATA, on the east by the tribal area adjoining Dera- Ismail -Khan district of NWFP and Musakhel district, on the south and south-west by Loralai and Killa Saifullah districts. Total area of district is 20297 square kilometers. Topographically, the district is covered with mountains and hills intersected by the broad valley of Zhob and its tributaries. The Toba- Kakar range covers the western half of the district extending from the boundary of Afghanistan up to the Zhob River. The general elevation of the district is 1500 to 3000 meters.

On the south of Zhob valley, a succession of parallel ridges running from north-east to south-west divide the drainage of the Zhob from that of the Bori valley in the Loralai district.

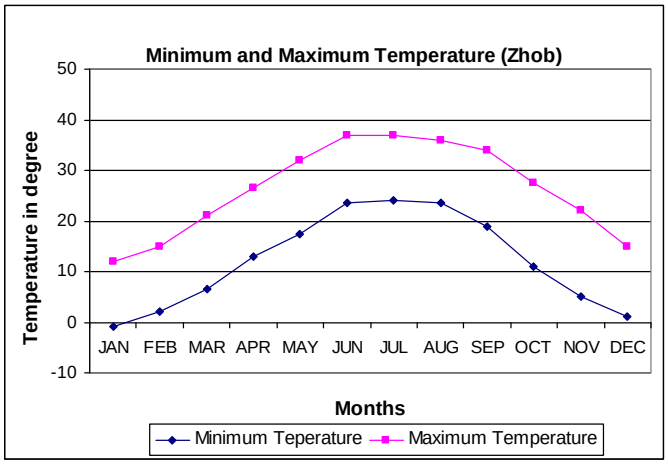
Monthly temperature and rain are shown in figure 2 (a and b). The climate of the district is hot and dry in summer and cold in winter. June is the hottest month with mean maximum and minimum temperature of about 37°C and 23°C respectively. January is the coldest month with mean maximum and minimum temperature of about 13°C and -1°C degree respectively. The dust- storms occur in summer from July to September accompanied by thunderstorms. In winters the wind blows from the west and is very cold. The winds from the Southwest and east are also common, the later invariably brings rain. The wind from the north occasionally blows during September to April bring drought and damage standing crops. Rainfall is scanty and varies with the altitude. Most of the rainfall is received during winter seasons. The district is one of the biggest districts in Balochistan. The land use table 2 below shows that only 4% of the total geographical area is as yet reported.

Table 2: **Land use statistics for Zhob**

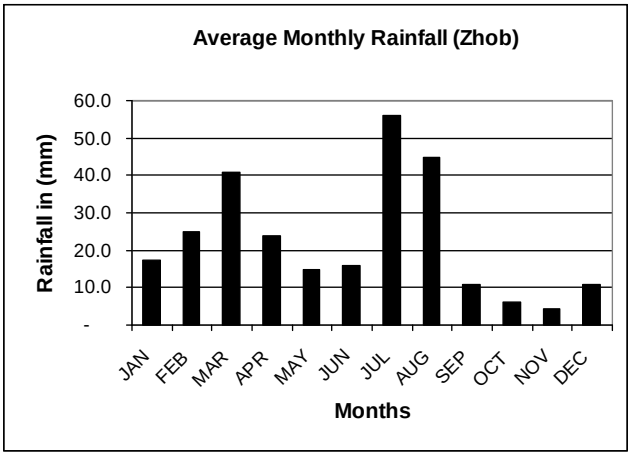
Land use	Area (Ha)	%age of total district area
Total Geographical Area	1,651,787	100
Area not Reported	1,590,857	96
Area Reported	60,980	4

- Not available for cultivation	10,853	0.7
- Area under Forest	13,010	0.8
- Culturable waste	13,387	0.8
- Area under water logging / Salinity		
- Arable land	23,730	1.4
Potential area available for cultivation	37,117	2.2

The soil of Zhob district is rocky and shingle gravel. Vegetation and forest are spread over considerable parts of the district. Wheat, Cotton, pulses almond , apricot, cherry and pomegranate are the major agricultural produce of the area.



a) Monthly average of the minimum and maximum daily temperatures °C



b) Monthly average rainfall (mm)

Figure 2**:** Average Monthly Temperature, Precipitation and Sunshine at Zhob

Irrigation Practices

The two principal drainage channels of the district are the Zhob and the Kundar Rivers, flow into the Gomal River. The Zhob River rises at Tsari Mehtarazai pass, the watershed a distance of about 400 kilometers. The broad plain of the Zhob River is occupied by the alluvial formation. The Kundar River rises from the central and highest point of the Toba Kakar range, a few kilometers northeast of the Sakir. It constitutes boundary between Pakistan and Afghanistan territory for a considerable length. The other subsidiary rivers or streams are the Baskan, Chukhan, Sri Toi, Sawar, Surab, etc. Only 16,206 acres of land is irrigated throughout the district. Majority of the area in the district is irrigated by springs, perennial irrigation, flood irrigation and delay action dam/storage dam irrigation schemes.

Results and Discussion

The analysis of the major crops was done to analyze the sustainability of the Current Crop Pattern under drought conditions and the management of water resources in general. A model was developed using CROPWAT, Software. The results are shown in figures 3 and 4 for Gawadar and Zhob respectively.

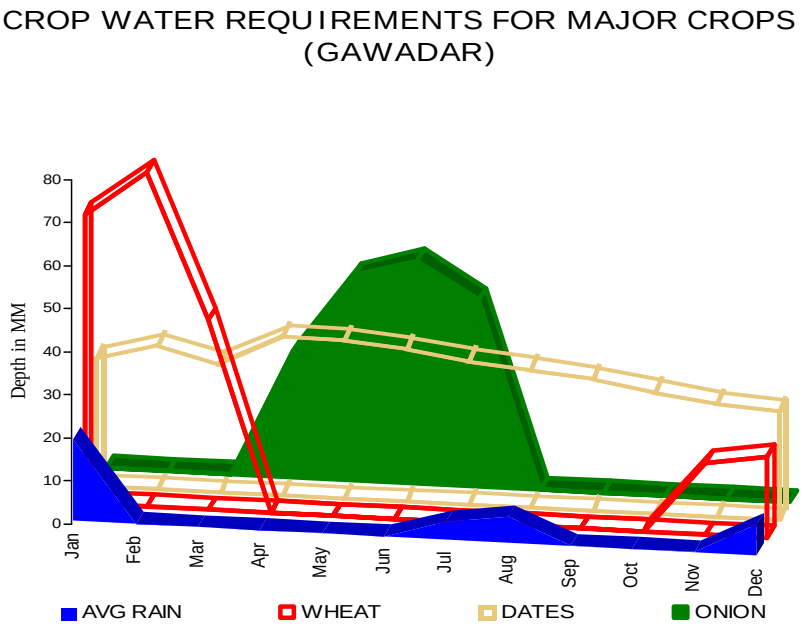


Figure 3**:** CWR for Major Crops and Average Rainfall Gawadar.

The model developed for Gawadar (Figure 1) shows that the average rain is not sufficient to meet High CWR (Crop Water Requirement) for wheat as wheat is grown mostly in un-irrigated areas of the district. On the other hand dates are ever green and can extract their CWR from sub surface water also they are mostly grown in irrigated lands. Onion also has CWR requirement during May to July and is not fit for rain fed areas except in heavy pre monsoon rainfall conditions. In case of Zhob (Figure 2) the crop water requirement for wheat in the study area can be met from the average rainfall. However storage is required to supplement the rain fall if the rain is below average. Sunflower, apple, cherry, potato and pomegranate have comparatively higher water requirement and need storage water in addition to the rain for proper growth. Potential for growth of pulses during September to December is high.

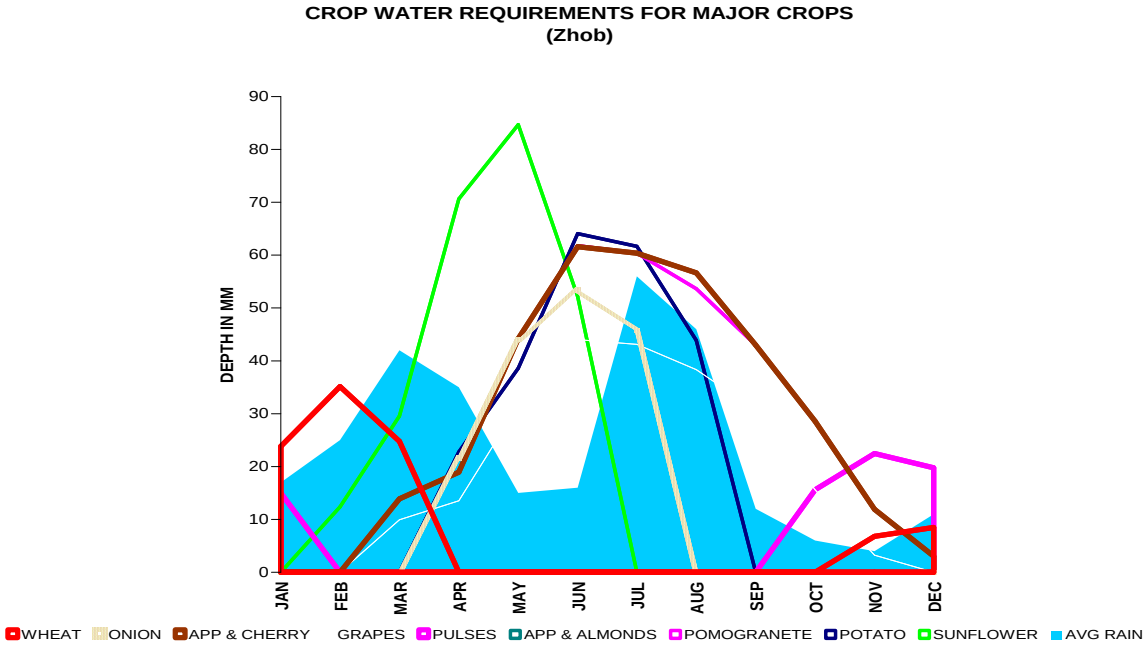


Figure 4**:** Analysis of Crop Pattern for CWR (Zhob)

CONCLUSIONS AND RECOMMENDATIONS

There is no easy solution to problem of water conservation in semi-arid regions as it varies from place to place and depends upon the local climate, soils, and vegetation and human requirements. It is observed that the average rainfall trend in Zhob suits the crop water requirements for wheat in study area but below average rainfall period storage is required for supplementary requirement to maintain the rate of production. Sunflower, apple, cherry, potato and pomegranate need storage water to sustain. Pulses has high growth rate during September to December is high.

In case of Gawadar the average rain is not sufficient to meet crop water requirement for wheat during peak season. Dates in Gawadar are ever green and can extract their water requirement from sub surface water also they are mostly grown in irrigated lands. Onion also has high water requirement during May to July and is not fit for rain fed areas of Gawadar.

From the discussion on the case studies regarding the cropping pattern the following recommendations can be made for better management of water resources under drought conditions.

- First of all a better communication for drought preparedness and forecasting needs to be established.
- An important aspect of drought prone areas-Soil degradation should also be controlled.
- Efficient Irrigation Techniques and new crop patterns should be tested through pilot projects at Local Government Levels for easy implementation and better participation. Crop Patterns with: Low Delta Crops mixed with High Delta Crops. Some examples are listed as: Oil seeds, Pulses, Local vegetables, Tree varieties, Grasses, Medicinal plants, Castor, Guar (cluster bean), Mung bean,
- Water harvesting and delay action dams are already being implemented but a lot more can be achieved through better participation of locals.

References

[1] Federal Bureau of Statistics (FBS), 2001), Statistics Division, Govt of Pakistan, “Pakistan Statistical Yearbook 2001”, April 2001.

[2] Kahlown, M.A., Majeed, A. and Tahir, M.A. (2002). Water Quality Status in Pakistan, Report 2001-02, Pakistan Council of Research in Water resources, report No. 121-2002, Islamabad, Pakistan, October 2002.

[3] MINFAL Ministry of Agriculture, Food and Livestock, Islamabad, Pakistan (1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003) Agricultural Statistics of Pakistan, Governament Press Islamabad.

[4] Hargreaves G. H. and Zohrab A. S., 1985, Reference Crop Evaporation from Temperature,, Applied Engineering in agriculture, Vol 1, issue 2, pp: 96, 99.

[5] Shakir A. S., Khan N. M. And Qureshi M. M., 2010, Canal Water Management: Case Study Of Upper Chenab Canal, In Pakistan, Irrigation & Drainage, Vol. 59, pp : 76-91

[6] Bastiaanssen W. G. M. and Chandrapala, L. (2003). “Water balance variability across Sri Lanka for assessing agricultural and environmental water use.” Agricultural Water Management, 58(2), 171-192.

[7] Bastiaanssen W. G. M, Noordman E. J. M., Pelgrum H, Davids G., Thoreson B. P., Allen R. G., 2005, SEBAL Model with Remotely Sensed Data to Improve Water-Resources Management under Actual Field Conditions. J. of Errigation and drainage Engineering ASCE, Vol. 131, No 1 pp: 85-93.

[8] Kuo, S., Ho s., Liu C., 2006, Estimation irrigation water requirements with derived crop coefficient, for upland and paddy crops in ChiaNan Irrigation Association, Taiwan, Agricultural Water Management, 82(3), 433-451.

[9] Ullah MK, Habib Z, Muhammad S. 2001. Spatial distribution of reference and potential evapotranspiration across the Indus Basin irrigation system. IWMI Working Paper 24, International Water Management Institute, Lahore, Pakistan.

[10] Laghari KQ, Lashari BK, Memon HM. 2008. Perceptive research on wheat evapotranspiration in Pakistan. Irrigation and Drainage 57: 571–584.

[11] Nazir A. 1993, “Water Resources of Pakistan”, Miraj uddin Press, Lahore September 1993.

[12] Allen R. G, Pruitt W. O., Raes D., Smith M., Pereira L. S., 2005, Estimating Evaporation from Bare Soil and the Crop Coefficient for the Initial period using common soil Information, ASCE, J. Irrigation and Drainage Engineering, Vol 131 Issue 14 (10 pages)