Water Requirements of Crops by Using the RS and Cropwat Model- a Case Study at Malayer Region, Iran

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Abstract

Considering the dangerous phenomenon of water shortage in recent decades throughout the world, more than 300 million people in 26 countries all over the world are facing water shortage. Based on the estimations, the number will increase to 66 countries and two third of the whole world population. High volume of data in the respective drainage and irrigation network has confused the programmers and managers with the accumulated unsorted and disorganized data in the computer. In this study, net derived demand (NDD) for irrigation water was derived based on Cropwat model and remote sensing and GIS techniques for Malayer in the west Iran in ten water years (1997-2006). Satellite images (IRS LissIII image), Cropwat model, coupled with GIS and RS were applied to compute net irrigation water requirements. Satellite images (IRS LissIII 11th June' 2006) were used to determine type and area of cultivated crops. Twelve main crops for Malayer were distinguished. Cropwat model was used to calculate real evapo-transpiration and (NDD) for irrigation water based on local climate data and information from agricultures on the satellite images. Groundwater is used for agriculture on the real data from the pump in the Region of Malayer.

1. Introduction

World population is increasing in alarming rate, this not only demands for more food but also supply of adequate drinking water is becoming a matter of concerns. With the economic and social development and basic reforms in the patterns of life on one hand, the limitation of available water sources have made it quite obvious to every society that how essential and vital water is. Considering water shortages in recent decades throughout the world, it may be said that there are more than 300 million people in 26 countries facing water shortages. Estimates show that this number will increase to 66 countries and two-thirds of the world population. The situation is highly critical when we consider the present population growth rate and large-scale investments in fundamental water issues. Researches on water resources of the world showed that Iran was among the regions with a per-capita recycled water source of 5000-10000 m^3 in 1950. It is anticipated that in 2025, the per capita recycled water source in Iran will be less than 1000 m^3.
A proper plan for the best exploitation of water resources in Iran, and by example in other countries, is necessary for consistent development. As almost 90% of the existing water resources are used in agriculture, it is quite obvious how essential is the proper exploitation of irrigation networks in order to get an optimum utilization of irrigation water and how necessary is an accurate programming for irrigation. There is also need for an efficient management in this field.
The average rainfall in Iran is about one-third of the World's rainfall average, and hence Iran encounters a severe shortage of water. On the other hand, as mentioned earlier, most of water sources are fully utilized for agriculture. Consequently, it is greatly important to use water efficiently to avoid any wastage. It is also necessary to save and utilize the limited water resources. This will be possible only through management practices by changing the way the water is distributed in the irrigation networks, repairing and renewing the existing networks, controlling and supervising the exploitation and utilization process, and using available hardware and software in this regard.
Combining management strategies such as time management, crisis management and risk management through available technologies such as satellites, software, and computer models can lead to positive results. Water resources and their spatial distribution determine the general character of any country in many respects of its potential economic development as well. Water stress or limitation is in upward swing in many countries due to the growth of population as well as industrial and agricultural production.
As we know, water is an irreplaceable natural resource, without which man can not exist. Therefore, in assessing the water resources of an area, the amount of fresh water is discussed.

Hydrological studies are the most important fields of modern hydrology. The results of these studies help to increase theoretical and practical knowledge about a geographical area. In this study, major emphasis has been given to determine the amount of irrigated lands, pattern of cultivation and water requirements of plants by using RS and Cropwat model in Malayer region, Iran.

2. Materials and Methods

In general, the research procedure is classified into two descriptive and analytic parts. The multi-spectral image captures differences in crop growth and represents these differences as NDVI values.

2.1. Data collection

A field study was conducted and ground information was collected using Global Positioning system (GPS) for Ground Control Point (GCP). Necessary support had also be taken from supplied statistic and information within the national statistical system, government documents, reports, researches, from library documents.

2.2. Data analysis

The image of IRS-LISSIII had been used for various analysis. Variations in the reflectance of surface materials across different spectral bands provided a fundamental mechanism for understanding features in remotely sensed imagery. Initial processing was importing images of satellite in software, radiometric correction, haze correction, geometric correction and image enhancement.

Selection of the best band combination was to make false colour composite image (FCC) and extracting the statistics from images. Climatic data analysis was done to prepare data input for the water budget and the Cropwat model. Information on weathering and groundwater were collected from meteorological data (monthly precipitation- mean monthly maximum and minimum temperature), cropping pattern drawn using ILWIS software. Moreover, quantity of surface water was estimated using hydrograph analysis and groundwater withdrawal was calculated based on available pumping data and using net irrigation water requirement approach.

2.3. CROPWAT model

CROPWAT is a decision support system developed by the Land and Water Development Division of the FAO for planning and management of irrigation. CROPWAT is a practical tool to carry out standard calculations for reference evapo-transpiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or at deficit irrigation. Procedures for calculation of the crop water requirements and irrigation requirements are based on methodologies presented in FAO Irrigation and Drainage Papers no. 24 *Crop water requirements* and no. 33 *Yield response to water*.

The development of irrigation schedules and evaluation of rainfed and irrigation practices are based on a daily soil-water balance using various options for water supply and irrigation management conditions.

2.4. Study area

Malayer region is situated in Hamadan province in Iran. This province is confined to Kurdistan and Kermanshah provinces in the west, to Qazvin and Zanjan provinces in the north, Markazy province in the east, Lorestan province in the south. This province with an area of 19493 km^2 includes 0.5% of country area. According to the last administrative divisions, the province has 8 townships, 24 cities, 23 districts, 72 rural districts and 1114 rural communities and 1098 villages (Table 1).

Malayer region is located in between 34° to 34°40’13" N latitude and 48°23’55" to 49°8’51" E longitude to the east of Greenwich meridian covering 3200 km^2 area in the southeast of Hamedan province. The area is surrounded by Hamedan city in the North, Touyserkan and Nahavand cities in the west, Lorestan province in the South and Markazi province in the East (Figure 1, 2, and 3).

The climate in Malayer is typically Mediterranean type with a mean annual rainfall of 305 mm. Major part of rainfall takes place mainly in between autumn to winter (65% of total), but not in summer. The temperature ranges from -1.4°C during December-January to 25.8°C in August.

2.5. Agriculture

At the study area, during 2006-2007 the area under cultivation was around 664,000 ha in which 40% is irrigated and 60% is used under dryland.

2.6. Irrigation

Irrigation method plays an important role in agricultural production, but unfortunately it is traditional in the Malayer region. The lack of rain and surface water has caused its heavy dependence on groundwater. An on-farm water application rate in the high and the irrigation practice has a low efficiency of around 31% for Malayer region. Besides the losses due to unlined irrigation canals, the largest losses at a farm level are due mainly to evaporation, inefficient irrigation practices (surface irrigation methods) and to the shallow of aquifers.

2.7. Wind speed

Wind is one of the significant factors in climatology which has a very important role in humidity due to Evapo-transpiration. Wind is a very parametric element in which the extent of magnitude and direction can be taken into consideration. Wind speed is another parameter that is necessary for the model Cropwat. This parameter at the study area was obtained from two stations. Generally, the wind speed to that applied in Cropwat model are in m/s, km/day, km/h at an altitude of 2 m from ground level, however the wind speed is recorded in knots at a height of ten meters of flat land. Wind speed data was converted to CROPWAT models using the following formula:

U2 = 4.868 / Ln (67.75Z-5.42)*Uz
Where:
U2 = Wind speed at two meters
Uz= Wind speed in Z meter elevation
Z = altitude of measured wind speed

2.8. Surface water

Malayer plain is located in the southern range of Alvand Mountain, and is part of the water basin of the upper part of the Karkheh River. The plain is limited to Alvand heights from the north parallel with the domed-shaped hill, Zard Mt. In the eastern part of the plain, the total the current direction of underground water is towards the North-west from the east and in the western area from the north-east part to the south-east. The hydraulic gradient is 4000-6000 in the southern region and 8000 in the northern and western regions. The study area consist some seasonal tributaries and permanent rivers. The major river system is the HaramAbad River.

Haram Abad Rivers in Malayer hydrologic unit includes Marvil, Kolan, and Gazandar rivers. Besides, there are various seasonal currents in Malayer hydrologic unit including Samen, Bayatan, Bidkorpeh, Darrechenar, Dehmianeh and Zalian rivers with 95 million m^3 out put off Malayer of Nahavand-Shivan hydrologic unit. The main characteristics of their sub-basins are summarized in Table 2.

2.9. Ground water

According to long-term piezometeric well data, minimum depth of water table is in May and April and maximum depth is in November and September at the study area (comprehensive studies project of Malayer Township).

3. Results and Discussion

3.1. Estimation of ground water withdrawal for irrigation

In order to know the amount of groundwater withdrawn for agricultural practices, agricultural well discharge data have been gathered from the Malayer Department of Irrigation. The data were helpful for the determination of the surface water available for irrigation, estimated net irrigation using Cropwat model and the amount of groundwater discharge prepared using the statistic of agricultural wells. The following steps were performed to estimate the quantity of groundwater for irrigation practices. The result of this estimate is shown in table 3.

3.1. Determination of irrigation areas by using the remote sensing technique

Remote sensing and GIS techniques are used to determine pattern of regional culture. IRS LISSIII were used for images from 11/06/2007. For image classification, it is firstly necessary to arrange a false color composite image (Figure 3). These images were interpretated through ILWIS software and classified by using the maximum likelihood algorithm into 12 classes. The surface area for each image class is also calculated (Table 4).

3.2. Calculated water requirements at the study site

Cropwat model has been performed using meteorological data, the pattern of cultivation, field work and interviews with farmers and Calendar Farm was prepared for various culture and garden products.

Then, Net irrigation requirements were calculated for each main product area (Table 5 and 6).

4. Conclusion

The Cropwat model is very sensitive to climatic conditions and crop growth data. Therefore, the input data of this model should have a high accuracy. This model is characterized by reasonable results for crops as compared to fruit trees. To run CROPWAT model, one needs to calibrate and validate the results obtained with the local lysimeter measurements. This model is one of the best tools in the world; this application was used to estimate crop water requirements at the study site. Remote sensing and geographic information system shows significant results but the information of the Agriculture Department is not very accurate. Therefore, it is better to use the satellite images. This study indicated that perennial plants can be better classified in comparison with annual plants. Results also indicate to change the existing traditional irrigation methods, otherwise farmers may face shortages of irrigation water.

5. Recommendation

- Utilizing GIS & RS in determining agricultural lands and optimum plantation modes.
- Establishing data bank of drainage and irrigation network to be utilized in GIS in different domains in connection with utilization and maintenance of water networks.
- Training more experts in handling GIS & RS.
- Using GIS and RS to make agricultural lands to take benefit from the mechanized agricultural along with implementing modern and traditional irrigation.
- Renewing water resources management by using CROPWAT software.
- Change in the pattern of cultivation is necessary because this region is insufficient to supply water for increasing irrigated area.

Table 1: Characteristic of population and agricultural lands in Hamadan province

Area under cultivation (ha)	Area (km^2)	population	Town ships
150262	4118	637304	Hamadan
98982	3210	290117	Malayer
59365	1535	181049	Nahavand
36718	1556	110737	Touyserkan
146836	3816	142645	Kaboodrahang
48287	1195	106208	Asad abad
74301	1334	122254	Bahar
105091	2729	113053	Razan

Table 2: Surface water uses in the Malayer irrigated area

Water years	Haramabad gauge	Marvil gauge	Total
1997-1998	75.37	11.95	87.32
1998-1999	20.21	5.23	25.44
1999-2000	17.34	3.34	20.38
2000-2001	18.73	9.86	28.59
2001-2002	89.94	7.61	97.55
2002-2003	71.79	9.12	80.91
2003-2004	60.82	15.69	76.51
2004-2005	52.94	12.3	65.24
2005-2006	33.39	9.43	42.82
2006-2007	28.45	9.11	37.56

Source: Comprehensive studies project of Malayer township

Table 3: Water use for agricultural practice for the Malayer area

Water years	Supplied by ground water	Supplied by surface water	Net irrigation water requirements
1997-1998	246.1	87.32	333.42
1998-1999	269.30	25.44	341.74
1999-2000	330.12	20.38	350.50
2000-2001	335.31	28.59	363.90
2001-2002	290.20	97.55	387.85
2002-2003	288.28	80.91	369.19
2003-2004	286.31	76.51	362.82
2004-2005	281.19	65.24	346.43
2005-2006	276.23	52.82	329.05
2006-2007	273.15	37.56	310.71

Table 4: Comparison of land area using satellite image

Planted area (Crop type)	Agri-Office		Satellite image	
	Area (ha)	%	Area (ha)	%
Winter crop	18658	46.96	23743	52.44
Summer crop	2942	7.40	6189	13.67
Forage plants	3600	9.07	2574	5.68
Grape	10,000	25.17	8651	19.11
Orchards	4531	11.40	4119	9.10
Total	39731	100	45276	100

Table 5: Net Irrigation water requirements (mm/period) for the Malayer area

Particulars	Year									
Crop Type	96-97	97-98	99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07
Winter crops	300	355.3	362	400.2	485	523	533.7	541.5	522.7	519.9
Summer crops	558.4	569	573.3	600.1	639.8	659.4	682.6	692	680.6	676.1
Alfalfa	709	712	735.7	801	843.3	868	823.2	780.8	765.7	759.4
Grape	458	469	511.6	525.4	541	573.5	602	570.6	560.3	558.5
Orchards	540.8	580.9	616	639.4	682.1	711	729.1	697.2	683.1	679.8
Total	2566.2	2686.2	2798.6	2966.1	3191.2	3334.9	3370.6	3282.1	3212.4	3193.7

Table 6: Total irrigation water requirements for the Malayer area

	Year									
Crop Type	96-97	97-98	99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07
Winter crops	80.42	79.64	83.71	80.86	90.53	78.94	75.42	68.29	64.81	58.65
Summer crops	42.81	44.69	46.68	45.01	56.52	46.36	43.68	40.29	38.63	36.57
Alfalfa	72.68	74.39	77.53	82.93	81.14	85.49	83.87	84.10	80.64	74.59
Grape	84.60	89.61	90.57	92.26	100.13	91.82	96.91	100.16	94.68	87.39
Orchards	48.91	52.41	54.34	63.72	65.59	67.78	60.63	64.05	56.49	53.78
Total	329.42	336.74	352.83	368.78	393.91	378.39	360.51	356.89	335.25	310.98

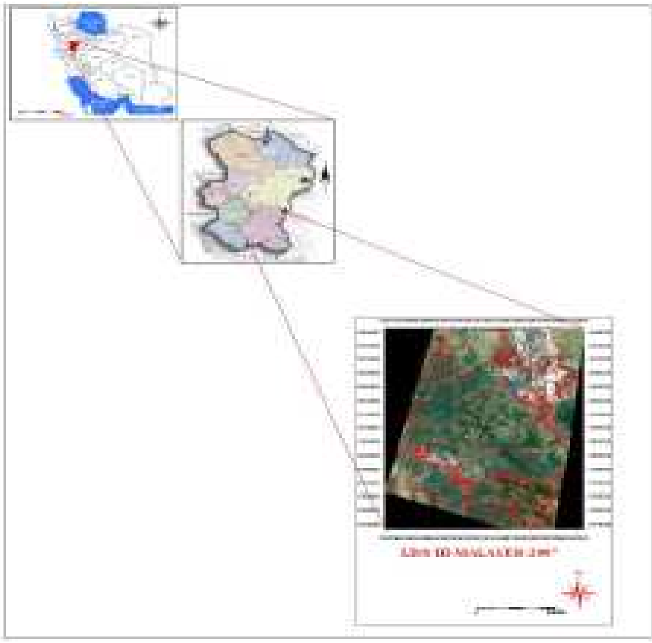

Figure 1: Map of Iran (highlighting Hamadan Province and Malayer region)

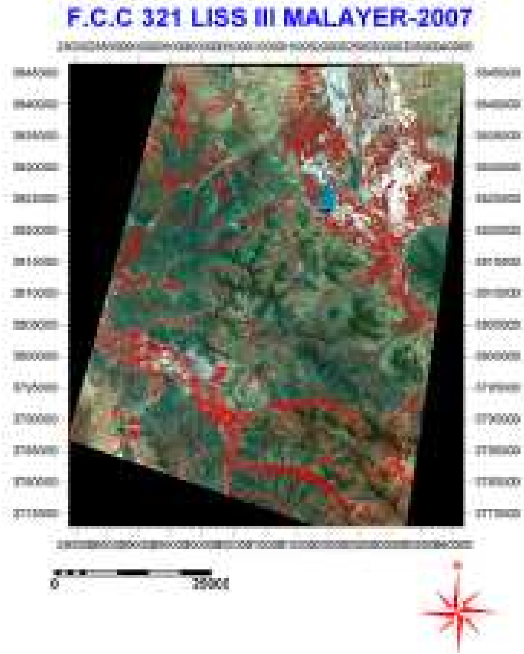

Figure 2: F.C.C LISS III of Malayer region

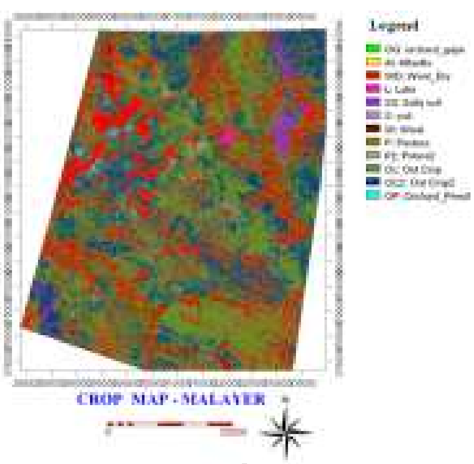

Figure 3: Crop map at malayer region