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Assesment of Crop and Irrigation Water Requirements for Some Selected Crops in Northwestern Bangladesh

Md. Robiul Islam [α], Mahmudul Hasan Mizan [σ], Mafruha Akter [ρ] & Golam Zakaria [ω]

Abstract- Currently, almost 90% of the global water consumption is caused by the irrigation activities, and more than 40% of the crops are produced under the irrigated conditions. This study is an attempt to estimate the irrigation water requirement (IWR) and crop water requirement (CWR) for some selected crops (Aus, Amon, Boro, Maize, Potato, Bean, Sugarcane, Banana, Tobacco, Wheat, Tomato, Peas, Groundnut, Peeper, Cabbage and Watermelon) in northwestern Bangladesh. Two selected districts (Dinajpur and Rangpur) and an adjacent upazila of Saidpur of Nilphamari district have been taken as a case study area. Necessary meteorological (rainfall, temperature, humidity, wind speed, sunshine hours) and crop data (crop coefficient and crop calendar) have been collected for 30 years period from 1982 to 2012. FAO CROPWATv8.0 has been applied for necessary calculation of CWR and IWR along with the developing of cropping patterns. The FAO Penman-Monteith method is used for estimating the reference evapotranspiration (ET_0) by using meteorological data in the framework of CROPWAT model as it regarded as a good estimator for a wide variety of climatic conditions. The analysis indicates that FAO Penman-Monteith suits very well for the study area and can be successfully used. The estimated monthly ET_0 demonstrates that evaporative demand from month April to October is very high, which reveals that the water losses are very high in these months. The obtained CWR for the selected crops indicates that maximum water requires for Rice. It also shows that Wheat, Peeper, Sugarcane and Banana exhibits comparatively higher water requirement than the other crops grown in the study area. The study concludes that IWR for month June to September is relatively low but for the other month irrigation requirements are comparatively very high due to the prevailing monsoon season in that period. The study also concludes that total IWR for Rangpur, Dinajpur and Saidpur are 644714, 1004745, and 47474 million liters, respectively only for the selected crops.

Keywords: irrigation water requirement (IWR), crop water requirement (CWR), crop calendar & co-efficient, reference evapotranspiration (ET_o), FAO penman-monteith.

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I. Introduction

Agriculture is the largest producing sector of Bangladesh's economy, contributing about 18.6% to the national GDP and employing about 45% of the total labor force. More than 85% of the country's population is directly and indirectly dependent on agriculture. The performance of this sector has great impact on the major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security(Abdullah and Rahman, 2015). Agriculture is responsible for about 75% of global freshwater diversions and 40% of the world's food is provided by irrigated agriculture on 20% of the world's cultivated land area(Shiklomanov, 1991). Though Bangladesh is a land of rivers, irrigation plays a vital role for half of the year when scarcity of water seriously handicaps farming operations. Irrigation is one of the leading input has direct influence to increase yields, food grain productions and plays vital role for increasing food security. Despite technological advances, agriculture is still vulnerable to the unfavorable weather events and climatic conditions.

Bangladesh is one of the most vulnerable countries in the world to climate change.Disaster and climatic risk management in agriculture is a major challenge for Bangladesh in achieving sustainable agricultural development(Abdullah and Rahman, 2015). Due to the increase in temperature, evapotranspiration (ET- water lost by evaporation and by transpiration) increases, resulting an increase in irrigation need. When the crop is small evaporation is the main process but transpiration becomes the dominant process after the crop is fully grown. There is no easy way of distinguishing evaporation and transpiration since they occur simultaneously (Zotarelli et al., 2009). It has been estimated that at crop sowing 100% of the total ET comes from evaporation while at full crop evaporation accounts for 10% of ET and transpiration for the remaining 90%.(Allen et all.,1998). Again the evapotranspiration from crops grown under management and environmental conditions that differ from the standard conditions is calculated by a water stress co-efficient (K_s) (Savva and Frenken, 2002). On the other hand higher rainfall will complement the irrigation. These contradictory phenomena will change

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the dryness in climate and the total irrigation demand which is required to quantify for long term irrigation planning and management. Water requirement for irrigation is closely related to population, demand for food, production of non-food agricultural and industrial items, improvement in quality of life and preservation of ecology and environment.

Bangladesh has a land area of about 14.4 million ha of which 9.03 million ha (64%) are under cultivation. Irrigation is one of the leading inputs has direct influence to increase yield, food grains production and plays vital role for ensuring food security in Bangladesh (Rahman and Parvin, 2009).Irrigation is currently available to less than 50% of the land that can be irrigated in the Rabi season. At present, about 33% of the cultivable land (3.12 million ha) has irrigation facilities. This amounts to about 21.6% of the total cropped area. The percentage of total cultivable area under irrigation can be increased to a greater extent if proper irrigation system can be applied.To be able to plan effective irrigation schedule, the steps were followed as stated in (Kariyama, 2014) The application of proper irrigation system depends on appropriate estimation of crop water requirement (CWR) and irrigation water requirement (IWR), effective rainfall, suitable cropping pattern and appropriate irrigation system.

II. Methodology

The objectives of this study is to estimate the CWR and IWR and to developed cropping pattern in the study areas for the selected crops to ensure the optimum use of available irrigation water and the optimum use of the available land. So assessment of evapotranspiration loss, effective rainfall and the percentage of total area covered by each crops is very essential. Again to ensure the minimum loss of irrigation water crop coefficient at different stages with their stage lengths and various climatic parameters are adjusted for the study areas.

a) Study Area Selection

Two districts Rangpur and Dinajpur and an upazila named Saidpur of Nilphamari districts in the northwestern zone of Bangladesh are selected as the study area.

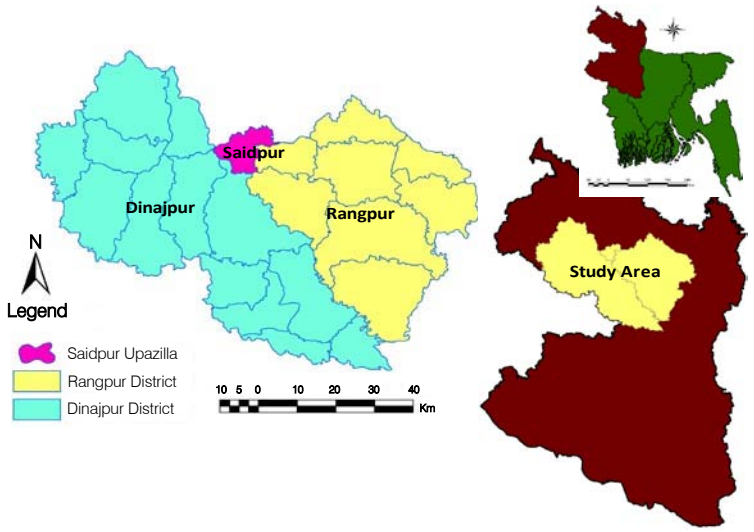

Figure 2.1: Location of the Study Area in Northwestern Bangladesh

Table 2.1: Study area latitude longitude and elevation (Source: Bangladesh Meteorological Departerment and Department of Agricultural Extensions)

Name of the stations	Latitude (N)		Longitude (E)		Elevation (Meter)	Total Area (Km^2)	Cultivable Area (Km^2)
	Deg.	Mts.	Deg.	Mts.			
Dinajpur	25	39	88	41	37.58	3437.98	2166..61
Rangpur	25	44	89	16	32.61	2707.78	1701.13
Saidpur	25	45	88	55	39.60	121.68	96.33

b) Data Collection

Various climatological data such as monthly maximum and minimum temperature, monthly average humidity, monthly average sunshine hours, daily average wind speed, monthly total rainfall, altitude, latitude, longitude are collected from Bangladesh Meteorological Department (BMD), Agargaon, Dhaka. Total area, total cultivable area, total area under

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irrigation, planting date, harvesting date, stages length, rooting depth and percentage of the total area covered by each crops are collected from Department of Agricultural and Extension (DAE), Rangpur for all the study areas. The other data such as crop coefficients at various stages, yield response, critical depletion factors are collected from FAO table and then adjusted.

c) Data Processing

The estimation of all the climatic parameters are made based on Least Square Parabolic Method. In case of any missing data for a year, value of that parameters for that year are predicted from the previously available data.

d) Reference Evapotranspiration (ET_0)

Although over the last 50 years several empirical and semi empirical method has been developed for the determination of ET_0 but the FAO Penman-Monteith is now sole recommended. The Penman-Monteith Equation for determining reference evapotranspiration (ET_0) is given by the following equation (FAO 1998 a)

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

To ease the calculation, Food and Agricultural Organization (FAO) developed a software named CROPWAT v 8.0. The following figure shows the determination of reference evapotranspiration using CropWatv8.0.

Monthly ETo Penman-Monteith - C:\Documents and Settings\All Users\Application Dat...

Country Bangladesh Station Rangpur

Altitude 33 m. Latitude 25.75 °N Longitude 89.27 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	8.1	26.6	81	26	3.1	9.4	1.55
February	10.0	30.5	70	35	5.6	14.0	2.36
March	14.2	34.7	66	52	5.5	15.9	3.29
April	18.3	35.7	75	86	6.4	18.8	4.26
May	20.1	36.5	78	52	6.2	19.3	4.32
June	21.6	35.5	82	50	4.2	16.4	3.77
July	23.0	35.9	81	69	5.1	17.6	4.10
August	24.3	36.2	83	52	4.3	15.9	3.73
September	24.5	35.1	82	43	6.5	17.8	4.00
October	19.3	34.1	80	35	6.5	15.7	3.30
November	13.6	30.6	77	35	6.3	13.4	2.46
December	9.0	28.3	82	17	2.8	8.6	1.54
Average	17.2	33.3	78	46	5.2	15.2	3.22

Figure 2.2: Evapotranspiration of Rangpur Using FAO CROPWAT v-8.0

The CROPWAT v 8.0 required the following crop data as shown in table 2 as input. From the crop data the crop coefficient values are adjusted.

Table 2.2: Input data in CROPWAT v 8.0

	Non-rice crop	Rice crop
Input Crop Data	➢ K_C values at different stage ➢ Different stage lengths ➢ Rooting depth ➢ Critical Depletion fraction ➢ Yield response and ➢ Crop height	➢ K_C dry values at different stage ➢ K_C wet values at different stage ➢ Different stage lengths ➢ Rooting depth ➢ Pudding depth ➢ Critical Depletion fraction ➢ Yield response and ➢ Crop height ➢ Nursery area

After adjusting the crop coefficient values the data are plotted as shown in the following figures:

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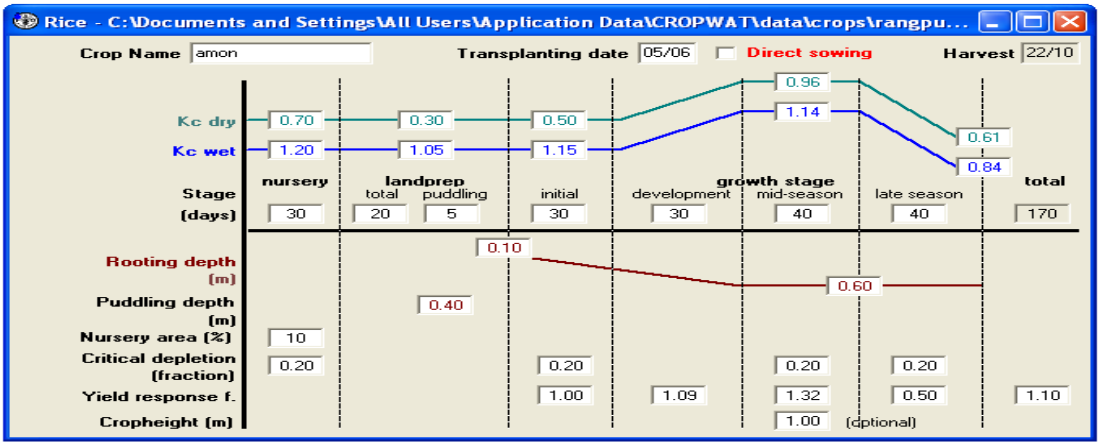

Figure 2.3: Rice data plotting for CROPWATv8.0

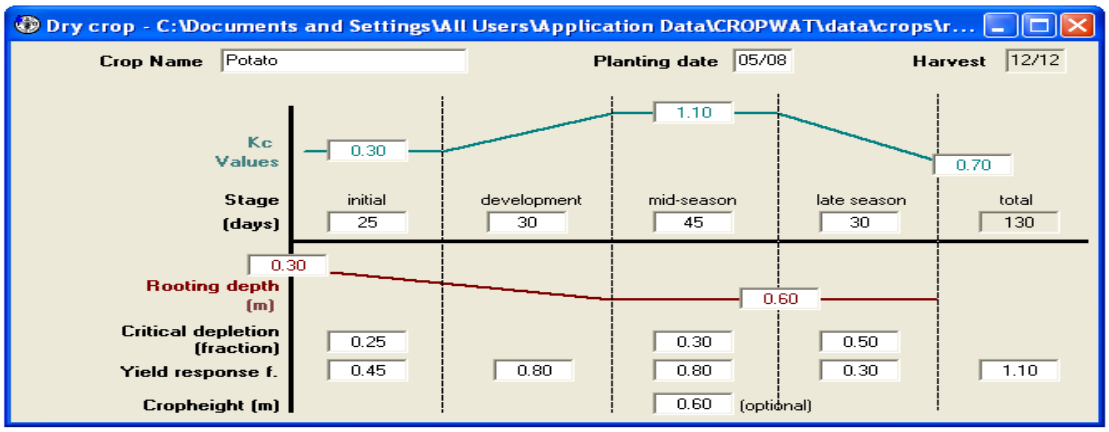

Figure 2.4: Non-rice data plotting for Rangpur station for CROPWATv8.0

After plotting the crop data, the required CWR and IWR for that particular crop estimated.

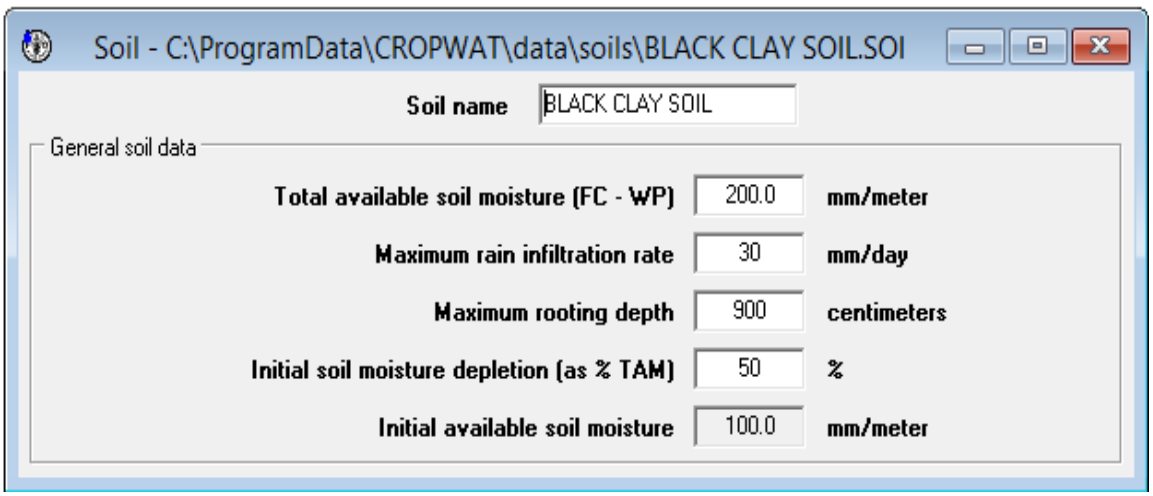

Figure 2.5: Soil Data Input for CROPWAT v 8.0

e) Cropping Pattern

To get the irrigation water requirement on daily or monthly basis for all the crops, a cropping pattern with planting and harvesting date with the total percentage of cultivable land covered by the each crops are inserted in the cropping pattern menu of the Cropwatv8.0.

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f) Total irrigation Water Requirement

After inserting cropping pattern, CROPWAT v 8.0 provide net scheme irrigation water requirement for that particular study area and for all the crops at a time.

III. Results and Discussion

a) Reference Crop Evapotranspiration of the Study Area

Figure 3.1 shows the estimated reference evapotranspiration of Rangpur, Dinajpur and Saidpur for all the month of 2013. From this figure we found that the reference evapotranspiration are normally less from the month November to February and their values are below 3 mm/day. For month Mar to October its value ranges from 3 to 5 mm. For most of the month the evapotranspiration losses are greater for Saidpur district compared to Rangpur and Dinajpur. Although there is an increasing tendency of the values from December to May but the value decreases in month Jun and July due to the heavy rainfall and low temperature. Rangpur, Dinajpur and Saidpur shows the maximum value of evapotranspiration in month May, August and May respectively.

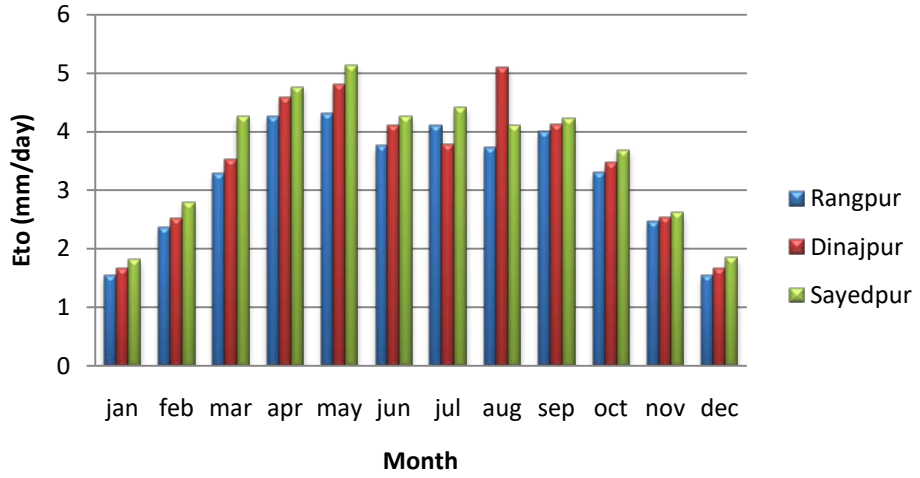

Figure 3.1: Monthly ET_O of Rangpur, Dinajpur and Saidpur

b) Estimation of Effective Rainfall

Figure 3.2 represents the estimated rainfall and effective rainfall of the selected stations. From figure it is found95% of the rainfall occurs during April to October, leaving the winter months, i.e. November to March, very dry. Therefore, irrigation is a prerequisite for obtaining stable high yields during the dry season hence irrigation water requirements for month November to March are very high so that crop can make intensive use of the land. The rainfall intensity is the maximum from month May to August. The rainfall intensity from November to March is very lower. April, September and October shows moderate rainfall. The maximum intensity of rainfall for Rangpur and Dinajpur occur in month Jun and for Saidpur occurs in month August.

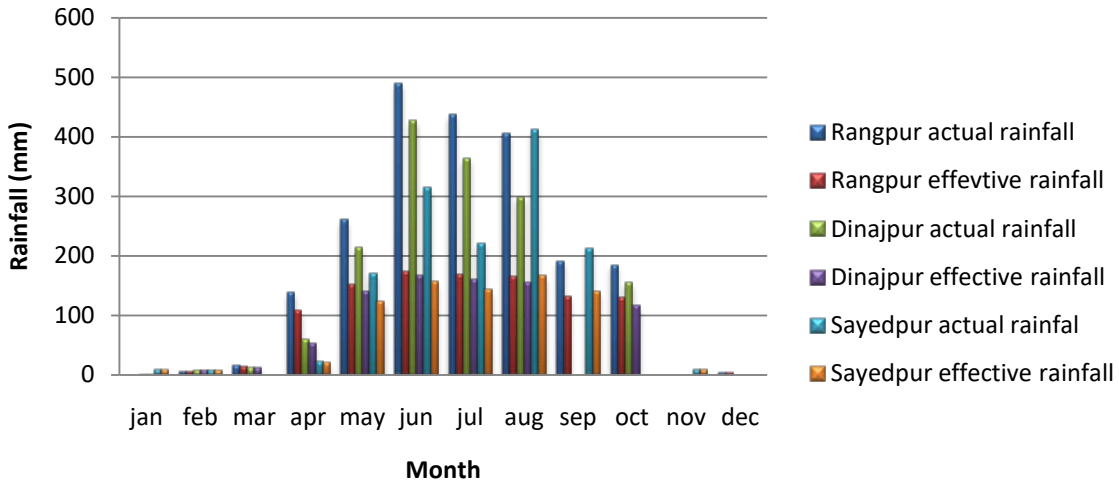

Figure 3.2: Actual and effective rainfall of Rangpur, Dinajpur& Saidpur for all the months.

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c) *Net Scheme Irrigation Water Requirement in the Selected Area*

Figure 3.3 shows the irrigation requirement only for the selected crops. From the figure it is found that the minimum irrigation requirement is from month Jun, July and Aug because in these periods rainfall intensity is the maximum. Again from month October to May irrigation water requirement is the maximum. For Saidpur in October month net Scheme irrigation requirement is maximum and excessively higher than the other months because of severe drought condition in this month.

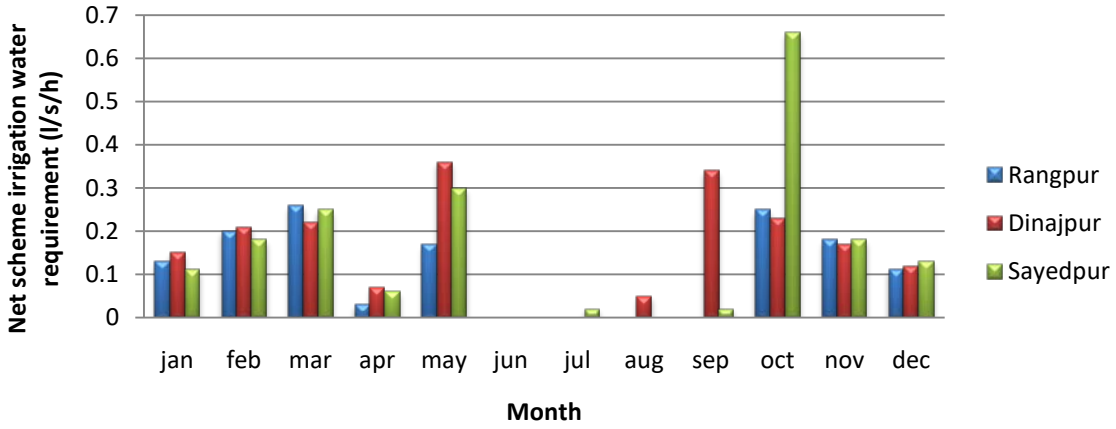

Figure 3.3: Net scheme IWR for Rangpur, Dinajpur and Saidpur for all month

d) *Crop water requirements for the selected crops in the study area*

Figure 3.4 shows the CWR of Various crops in their lifetime and expressed in mm. On the basis of total crop water requirement per unit area Banana shows maximum CWR. If we consider Daily basis or total CWR in the area where it is cultivated then rice require the maximum CWR as rice grown in a huge area.

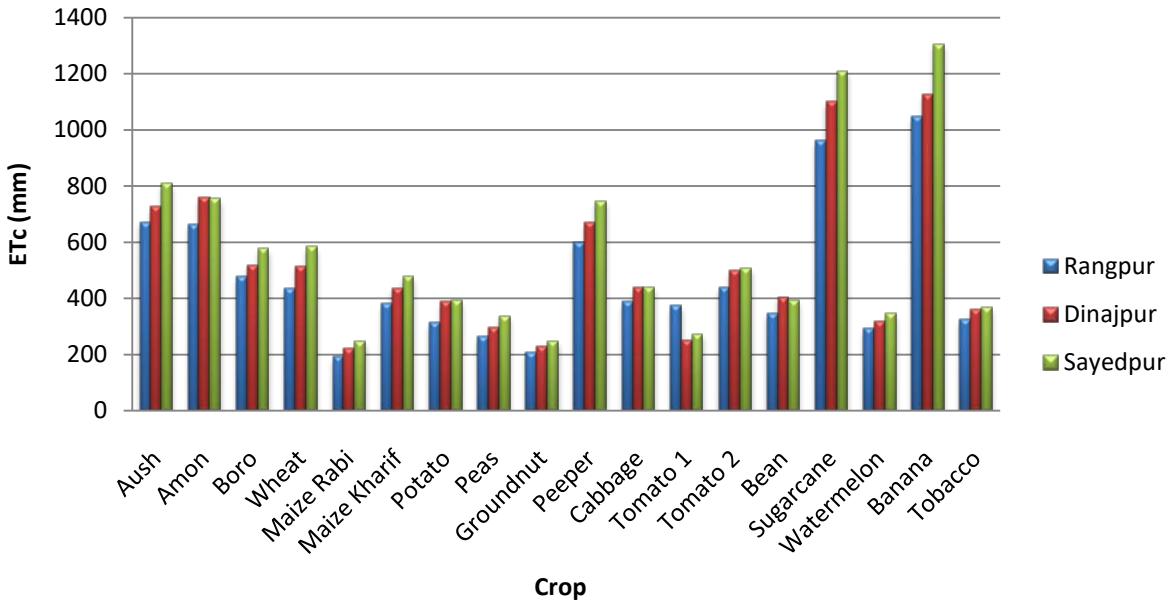

Figure 3.4: Crop water requirements for the selected crops for the Rangpur, Dinajpur and Saidpur

e) *Cropping Pattern in the study area*

The following figure shows the cropping pattern of Rangpur based on the Planting and Harvesting date and the percentage of total area that each of the crop occupied. The above figure gives an idea about the total area that a crop is cultivated. From Peas to Banana it is found that the percentage of total area is 1% for each of the crop when using CropWatv8.0. This is because CropWatv8.0 does not take in value less than 1 during the development of cropping pattern. This ensures the yield of more production for the other crops. Rice is cultivated in most of the area followed by Potato, Maize, wheat etc.

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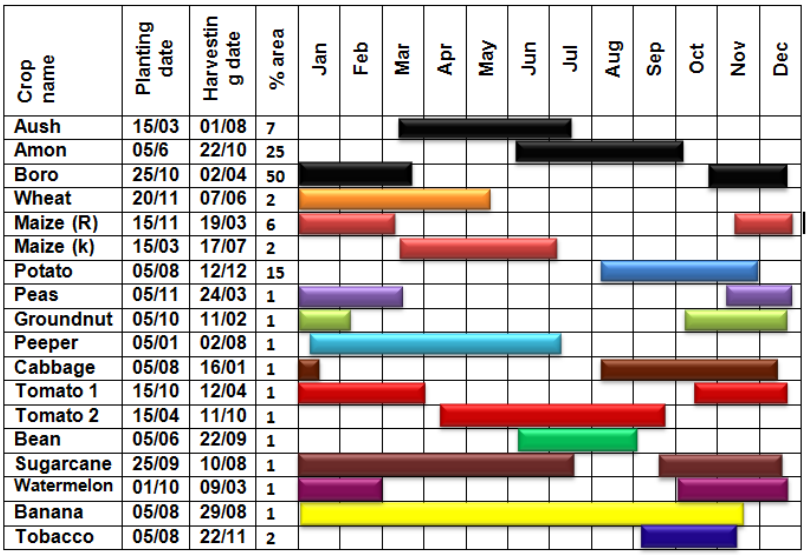
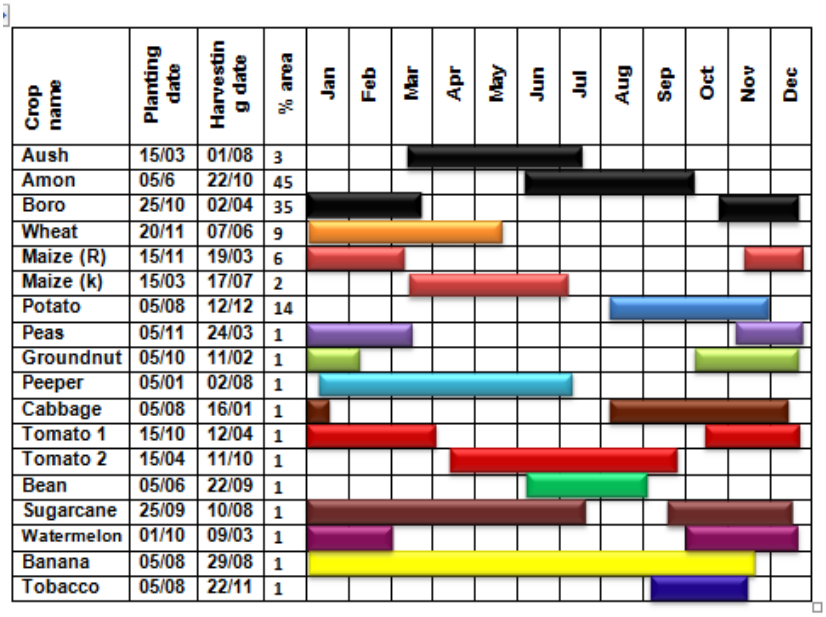


Crop name	Planting date	Harvesting date	% area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aush	15/03	01/08	7												
Amon	05/6	22/10	25												
Boro	25/10	02/04	50												
Wheat	20/11	07/06	2												
Maize (R)	15/11	19/03	6												
Maize (k)	15/03	17/07	2												
Potato	05/08	12/12	15												
Peas	05/11	24/03	1												
Groundnut	05/10	11/02	1												
Peeper	05/01	02/08	1												
Cabbage	05/08	16/01	1												
Tomato 1	15/10	12/04	1												
Tomato 2	15/04	11/10	1												
Bean	05/06	22/09	1												
Sugarcane	25/09	10/08	1												
Watermelon	01/10	09/03	1												
Banana	05/08	29/08	1												
Tobacco	05/08	22/11	2												

Figure 3.5: Cropping Pattern of Rangpur

Based on planting and harvesting date and total percentage of area that the crops are cultivated, cropping pattern for Dinajpur shown in figure 3.6 is prepared using CropWatv8.0. Rice is cultivated in most of the area followed by Potato, wheat, Maize etc.



Crop name	Planting date	Harvesting date	% area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aush	15/03	01/08	3												
Amon	05/6	22/10	45												
Boro	25/10	02/04	35												
Wheat	20/11	07/06	9												
Maize (R)	15/11	19/03	6												
Maize (k)	15/03	17/07	2												
Potato	05/08	12/12	14												
Peas	05/11	24/03	1												
Groundnut	05/10	11/02	1												
Peeper	05/01	02/08	1												
Cabbage	05/08	16/01	1												
Tomato 1	15/10	12/04	1												
Tomato 2	15/04	11/10	1												
Bean	05/06	22/09	1												
Sugarcane	25/09	10/08	1												
Watermelon	01/10	09/03	1												
Banana	05/08	29/08	1												
Tobacco	05/08	22/11	1												

The following figure shows the cropping pattern of Saidpur based on the Planting and Harvesting date and the percentage of total area that each of the crop occupied. The above figure gives an idea about the total area that a crop is cultivated. Rice is cultivated in most of the area followed by Potato, wheat, Maize etc.

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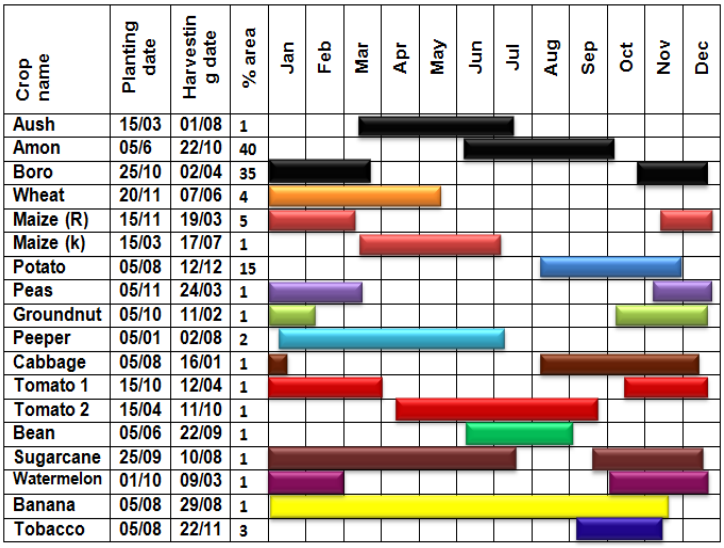

Figure 3.7: Cropping Pattern of Saidpur

IV. Conclusions

Based on the present study the following conclusion can be drawn:

- This study mainly estimates the CWR and IWR for some selected crops as well as developing cropping pattern for the study area using CROPWATv8.0
- IWR is very low from June to September due to higher rainfall intensity in these months and from month October to May a considerable amount of water is required for irrigation.
- Total IWR for Rangpur, Dinajpur and Saidpur are 644714, 1004745, and 47474 million liters or 41.43 cusec, 66.73 cusec and 3.09 cusec respectively.
- Since the climatological conditions of Rangpur, Dinajpur and Saidpur are more or less same hence planting and harvesting date for various crops are kept same while developing cropping pattern.
- The maximum water requires for Rice crops, Wheat, Peeper, Sugarcane and Banana are comparatively higher than the other crops.

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