On test application of CropWAT software under field conditions of Semi-arid Region, Maharashtra

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CropWAT, Semi – arid region, Irrigation Schedules

ABSTRACT:
Crop management practices can play a key role in order to improve their water use efficiency and increase yield per drop of water. In order to facilitate this process, WOTR experimented with using CropWAT 8.0, developed by the FAO, and other precision farming techniques. CropWAT calculates irrigation schedules based on the climatic conditions. To identify the accurate parameters for calibration, higher levels of field test management skills would be required (to create fully controlled conditions at least for calibration purpose).This in the current study could not be achieved at field level and was found not feasible to the farmers to continue the process or replicate it. A full data set of climate, rain, and soil and crop data is required to run the software in order to make calculations. This implies that the calculations can only be made with climatic data from past or estimated weather predictions. This also implies that the software can calculate general irrigation schedules for a crop. Exact calculations of real time irrigation schedules are not possible under current field conditions. The second difficulty which emerged was pressure of external drivers which modify/dictate farmers' behaviors. The third barrier observed was that the software itself does not allow for automated import of the data. The data had to be fed manually into the software. This part is a significant barrier to the application of this software on a larger scale, it seems nearly impossible to operate the software in an extension environment where the extension staff has limited time and would need a quick and readymade tool. For this case other improved software with a similar methodology needs to be developed. This should be implemented in a web based weather database. It should allow automated calculated water requirements for specific crops, on real time weather conditions, for each farm and plot. There should also be the possibility to adjust the current crop to the field conditions and the availability of water and the effective applied irrigation water. But such kind of software can't be used as a single tool to make real-time irrigation advisories due to the complexity of the system. Field visits, soil moisture observations and farming experience can't be substituted by single software located away from the site. Furthermore the water availability over each season and for each farm is often unknown and makes it difficult do give irrigation advisories. The decision when to irrigate often depends on the availability of water and electricity. The farmers should be empowered to make better irrigation decisions by their own. This experiment showed that in principle it is easy to operate but it is very difficult to work with the software in a practical way under field conditions, where many parameters cannot be constantly checked.

1. INTRODUCTION

A proper crop management is the key point to increase the water use efficiency, respectively to reduce water losses and increase the yields per drop of water. For this purpose precision farming and different irrigation and water saving techniques should also be tested. The objective of the Study was to test CropWAT[1] application for developing a model case for the development of irrigation advisories at farm level.

CropWAT 8.0 for Windows is software to calculate water requirement and irrigation schedules and to evaluate farmer's irrigation practice. The calculation in CropWAT is based on soil, climate and crop data. The program uses the FAO Penman-Monteith (1992) methods for calculating reference crop evapotranspiration (ETo) (FAO 1998) and the crop water requirement (ETc). To calculate the ETc which is related to the ETo, the specific crop coefficients (kc) must be determined: $c = ETo * kc$. The kc factor depends on the crop leaf area and its roughness, the stag of the growth, the growing season. This software was tested and used in many studies in different parts of the world. The studies were mostly for scientific research purpose to calculate general water requirements for different crops. With the help of this software the current irrigation practices were evaluated and improved irrigation schedules were developed. Low information about the use of this software on farm level is available.

[1] CropWAT – Crop Water Assessment Tool.

One objective was also to find the accurate parameter, to calibrate this software for the use on field level.

2. MATERIALS AND METHODS

2.1. Study Area

The experiment was conducted in a valley of Sarole Pathar in the Sangamner 2 Cluster, Maharashtra India, at around 740 m a.s.l (19° 23.355'N, 74°11625'O) (Figure 22). The bottom of the valley is 70 m deeper than the Sarole Pathar village. A small water stream flows trough this valley, this is one of the less water sources, where water is running in Rabi season until it dries out in March or April. The yearly precipitation in 1959-2008 is around 400 mm. Onion is the main crop in Rabi season in this valley because of its high water demand and the high market demand.

Sarole Pathar is the village in a hilly terrain where the study-project on CropWAT has been implemented. This village is a middle catchment project village. Runoff water from some area of Gunjalwadi enters the Sarole Pathar through two different drains. It has three different micro watersheds. Runoff from Sarole Pathar is discharged through three different drains to Malegaon Pathar. The village consists of 277 households (HHs) with a population of 1351. Thereof 53% are male and 47% are female. 46 (17%) of farmers are landless. Farmers owning less than 2 ha of land constitute 48% of the HHs. So nearly fifty percent of the HHs are marginal farmers. In sum, approximately 75% of the HHs own less than 4 ha of land.

The soil is mostly very poor on organic matter. The soil texture is mainly clay, clay loam, having avg. depth of 15cm.The crops commonly grown in irrigated and rain fed area are wheat, chick pea (harbhara), sorghum (jowar), tomato and onion. Rain fed area covers 235 ha cultivated land, 50 households are involved in its cultivation. In Kharif season only some crops are taken under protective irrigation. These crops are onion, tomato, maize and groundnut. Their area under cultivation is less 3.1 ha. In rain fed areas, 7 crops are being cultivated with Pearl Millet (bajra), tomato and onion covering major area. During rabi season, some crops are taken in irrigated areas but their area is less at about 2.4 ha. In the rabi season 2011/2012 onion makes the covers the biggest part of it. In summer season only tomato is taken by one house hold, which has negligible area under cultivation.

2.2. Experimental Design

The study was conducted for Rabi onion crop, as it is one of the major crops under cultivation in Sarole Pathar. Soil samples were taken in both plots and given to the soil testing laboratories. The analysing results were used to make the fertilizer recommendations.
The plots were divided in five different sectors with different irrigation treatments.
1) Drip Irrigation,
2) Drip irrigation with mulch,
3) Flood irrigation
4) Flood irrigation with mulch,
5) Irrigation as usual

Each plot was of 1 Guntha (100m^2), total comprising of 5 Guntha. A gravity drip system for 200m^2 from Jain Irrigation LTD with a 1000 litre dual-layer sintex water tank was used in the Drip plots (1 and 2). The drip laterals with 30 cm emitter distance with a discharge of 4 l/h each were used. The distance between the laterals was 60 cm. The tank was placed in a 5 m higher elevation to get enough water pressure. The effective discharge of emitters was calculated on 1.2 l/h. The flood plots were prepared as common with 1 m wide sectors with 15 cm high boundaries. To measure the irrigation water amount, the discharges of the pumps were calculated. For the soil moisture monitoring, two tensiometers were installed for each treatment. In the onion plot the tensiometer were set at 30 cm depth. The farmers took the tensiometer readings in a daily interval and were controlled at least twice a week by WOTR Staff. These readings were required to calibrate the software CropWAT. The status of the crops was observed at least once a week; pictures and measurement were made each time.

2.3. CropWAT Calculations

The required climate data was collected in Sarole Pathar village with automated Davis Vantage Pro 2 weather station. The weather data were available from 1st January 11 to 31st March 2012. CROPWAT needs to have a full climate data of one year to calculate irrigation schedules. For our purpose we took the actual available data for the season November until end of March. With begin of April 12 the data from the last year (April 11) are used. The climate data were put in as monthly averages. The irrigation efficiency was set at 70% for drip plots and 50 % for flood plots. The irrigation was set to give at critical depth for both the methods of irrigation.

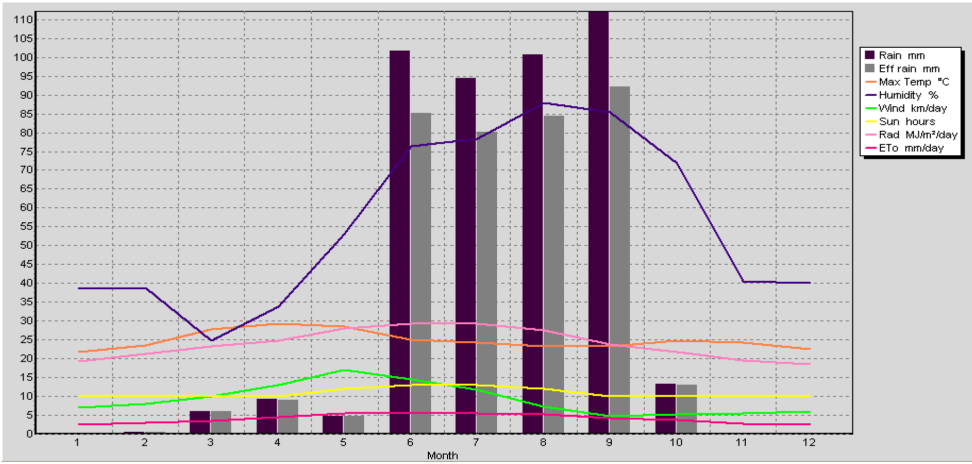

Figure 1. Sarole pathar weather conditions for the year 2011-12

The total water requirements and irrigation schedules based on CropWAT calculation for the onion crop for the Rabi season 11/12 are shown in the Figure 1. For Onion with crop duration of 150 days the total water requirement with out yield reduction is 490 mm. The total irrigation water requirement (total gross irrigation) came to be 430mm when irrigated with flood irrigation and 306 mm when irrigated with drip system. This should be given with 10 irrigation applications.

CROP IRRIGATION SCHEDULE

ETo station: Sarole Pathar   Crop: Green Onion   Planting date: 27/12
Rain station: Sarole Pathar   Soil: Clay Loam   Harvest date: 06/04

Yield red.: 0.2 %

Crop scheduling options
Timing: Irrigate at 100 % depletion
Application: Refill to 100 % of field capacity
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
27 Dec	1	Init	0.0	0.71	71	51	22.0	0.0	0.0	31.5	3.64
9 Jan	14	Init	0.0	1.00	100	32	16.9	0.0	0.0	24.1	0.21
23 Jan	28	Dev	0.0	1.00	100	31	20.1	0.0	0.0	28.7	0.24
4 Feb	40	Dev	0.0	1.00	100	31	23.6	0.0	0.0	33.7	0.32
14 Feb	50	Dev	0.0	1.00	100	31	25.4	0.0	0.0	36.2	0.42
25 Feb	61	Mid	0.0	1.00	100	33	27.6	0.0	0.0	39.4	0.41
7 Mar	71	Mid	0.7	1.00	100	31	25.9	0.0	0.0	37.0	0.43
17 Mar	81	Mid	1.0	1.00	100	32	26.9	0.0	0.0	38.4	0.44
27 Mar	91	End	1.2	1.00	100	32	26.6	0.0	0.0	38.0	0.44
6 Apr	End	End	0.0	1.00	0	29					

Totals:

Total gross irrigation	306.9	mm	Total rainfall	7.8	mm
Total net irrigation	214.9	mm	Effective rainfall	7.8	mm
Total irrigation losses	0.0	mm	Total rain loss	0.0	mm
Actual water use by crop	204.6	mm	Moist deficit at harvest	24.0	mm
Potential water use by crop	204.8	mm	Actual irrigation requirement	197.1	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	0.1	%			

Figure 2. Irrigation schedule for Rabi Onion (Drip Plots)

CROP IRRIGATION SCHEDULE

ETo station: Sarole Pathar   Crop: Green Onion   Planting date: 27/12
Rain station: Sarole Pathar   Soil: Clay Loam   Harvest date: 06/04

Yield red.: 0.2 %

Crop scheduling options
Timing: Irrigate at 100 % depletion
Application: Refill to 100 % of field capacity
Field eff. 50 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
27 Dec	1	Init	0.0	0.71	71	51	22.0	0.0	0.0	44.1	5.10
9 Jan	14	Init	0.0	1.00	100	32	16.9	0.0	0.0	33.8	0.30
23 Jan	28	Dev	0.0	1.00	100	31	20.1	0.0	0.0	40.2	0.33
4 Feb	40	Dev	0.0	1.00	100	31	23.6	0.0	0.0	47.1	0.45
14 Feb	50	Dev	0.0	1.00	100	31	25.4	0.0	0.0	50.7	0.59
25 Feb	61	Mid	0.0	1.00	100	33	27.6	0.0	0.0	55.1	0.58
7 Mar	71	Mid	0.7	1.00	100	31	25.9	0.0	0.0	51.8	0.60
17 Mar	81	Mid	1.0	1.00	100	32	26.9	0.0	0.0	53.7	0.62
27 Mar	91	End	1.2	1.00	100	32	26.6	0.0	0.0	53.1	0.62
6 Apr	End	End	0.0	1.00	0	29					

Totals:

Total gross irrigation	429.7	mm	Total rainfall	7.8	mm
Total net irrigation	214.9	mm	Effective rainfall	7.8	mm
Total irrigation losses	0.0	mm	Total rain loss	0.0	mm
Actual water use by crop	204.6	mm	Moist deficit at harvest	24.0	mm
Potential water use by crop	204.8	mm	Actual irrigation requirement	197.1	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	0.1	%			

Figure 3. Irrigation schedule for Rabi Onion (Flood Plots)

3. OBSERVATION AND RESULTS

3.1. Irrigation Schedules

The irrigation were applied when electricity for the water pumps were available. There was a change in the electricity schedule for this region. Electricity was available every second week at night time and in the other week at day time. The total irrigation water supply in the recorded period was 137'000 litres (457 mm) of water for the flood sections and 68'000 litres (340mm) for the drip sections. The recommendation to irrigate when the tensiometer shows water stress (Soil moisture tension below -40cbar) was not followed. The farmer irrigated by his own discretion. The figure 4 show the graph of the soil moisture readings. It is evident that the soil moisture tension was only one time at the end of the records near water stress level. The graphs in figure33 show a hug variability of soil moisture in the different flood sections. Only a little higher soil moisture could be measured after the mulching application at 17th January'12 on the drip section 1 (Tensiometer L1). In the flood section no differences in the soil moisture could be measured because of the mulching. The reason for this is that the mulch was washed away by the flood irrigation application.

3.2. Soil Moisture Readings

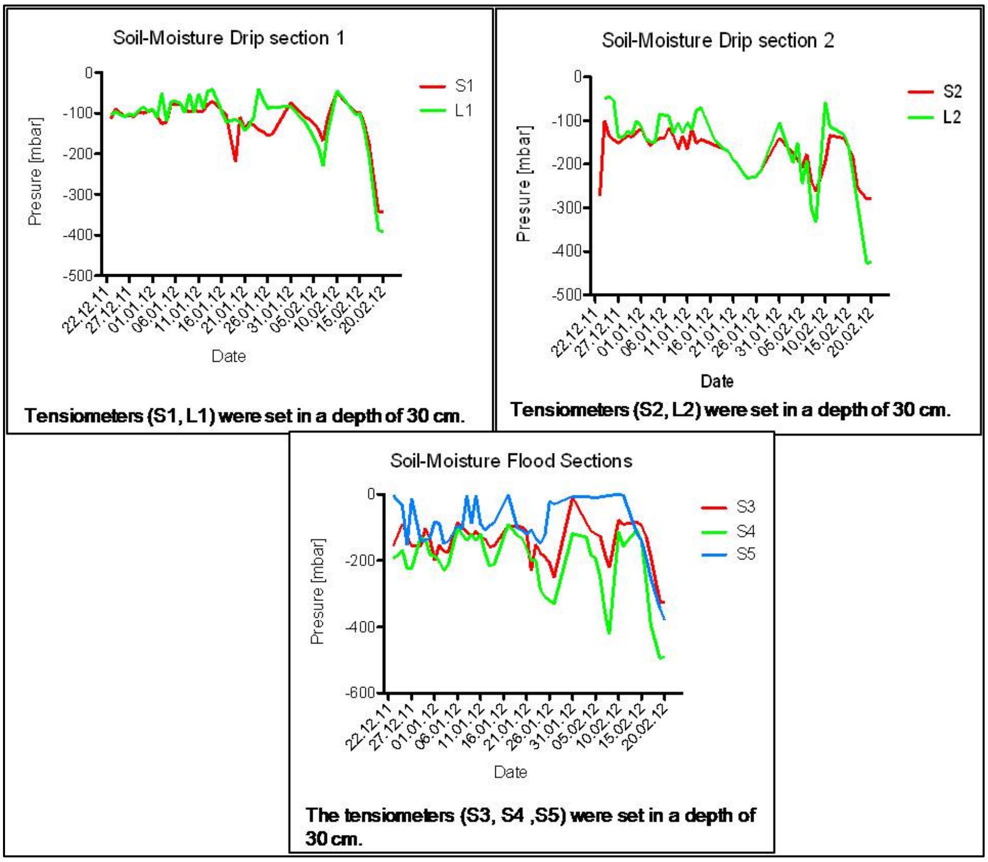

Figure 4. Soil stress shown in tensiometers

4. DISCUSSION

4.1. Field Observation

The field observations have revealed that the farmers did not follow all the planed and recommended crop management activity. Retrospectively it is difficult to judge whether the farmers didn't understand the recommendations or whether they didn't trust them and deviations happened on purpose or incidentally. The willingness to reduce the irrigation water input amount and to change the current farming practice was low (no commercial incentive felt). The onion farmer was interested to use bio fertilizer and micronutrients, but he didn't reduce the chemical fertilizer application. The effective time to irrigate the field was noted by the farmers. In the survey design there was no possibility to verify whether this data is correct or whether the farmers polished some of it in order to make it look nice. The tensiometer readings were also mostly taken by the farmers them self. The experiment on the onion plot could not be completed within the 6 month reporting time of this report, hence no quantitative results of the crop could be analysed and discussed.

4.2. Soil Profile and Soil Moisture Monitoring

The soil profiles show, that the soil is very poor of organic matter. Nearly no humus is available. The rooting zone is only 30 cm. This is followed by a very dens layer where the root can not grow through, the roots can absorb the water only in this top layer. It is questionable if the tensiometer readings of 90 cm depth are relevant for the plants.

The soil moisture monitoring with tensiometers in the onion plot show that the soil moisture went only once below the water stress level of -40 cbar towards the end of the survey period. This happened due to a defect on the water pump due to this the farmer couldn't irrigate his plot earlier. The figure 31and32 for the drip plot shows that the soil moisture in the beginning was nearly constant and later had more variability. This happened due to the change in the electricity supply schedule, which lead to a situation where the farmer could irrigate his plot only every second week. The figure 4 for the flood sections shows that there was a bigger variability of soil moisture in these sections. This was because the flood plot was irrigate only every 7 days. It shows also the differences in between the flood sections were hug. This could happen because the soil layers were not homogeneous or the irrigation amount was not the same for every section. The readings of the tensiometer S5showsthat the soil moisture was nearly saturated over a long time, which is not traceable.

The influence of the mulching in the onion plot shows no significant improvements respectively higher soil moisture. In the flood plot it happens because the mulching material was washed away due to the high amount of irrigation water. Another mulching technique has to be found for this particular irrigation technique.

4.3. Irrigation and CropWAT Calculations

The out put of CropWAT shows that the calculated water requirement differs from the effective applied irrigations. The onion plot had an expected irrigation water requirement of 430mm and 306 mm for the recorded period for flood and drip system respectively. This is less than half part of the effective applied water (457 mm) for flood section. The water application with 340 mm on the drip sections was also more. The farmer didn't trust the drip irrigation system and applied much more water than required. It reflects the difficulty for the farmer to adapt new technologies.

Due to lack of data and prevailing uncertainties the software couldn't be calibrated with the available experience and the available results. It is not evident whether or where the mistakes in the calculations occurred. They could be in the soil or crop parameters.

The interviews with farmers show that the farmers gave total different information about their current practice and what we saw what they really did in our experimental plots. The normal irrigation amount according to the farmer is only 340 mm. Normally the water requirement of onion is 350 – 550 mm (FAO). It is questionable if the information is correct; if they are correct it is questionable why they irrigate such a huge amount on experimental plot.

5. CONCLUSION

This experiment with this project to test the CropWAT software shows, that it is in principle easy to operate but it is very difficult to work with the software in a practical way under field conditions, where many parameters cannot be reliably checked. A second conclusion is the implementation of such farmers field tests need a very good preparation in advance to implement such experiments with success. This planning needs a broad of practical knowledge in different subjects including possible drivers of farmer behaviour. The understanding of the software and how to use it is only a very small part of the design of such a field test. The more difficult and challenging parts are how to obtain plausible soil and crop parameters to calibrate and feed the software. These parameters are not fully available from the software itself respectively from the FAO. The parameters have to be modified for the specific field situation; the respective assessments need knowledge on local conditions and a high level of experience. Further more a very good practical knowledge of farming practice in particular fertilizer-, pest- and disease management, are the basic requirement to use tools such as CropWAT. To identify the accurate parameters for calibration, higher levels of field test management skills would be required (to create fully controlled conditions at least for calibration purpose).This in the current study could not be achieved at field level.

A full data set of climate, rain, and soil and crop data is required to run the software in order to make calculations. This implies that the calculations can only be made with climatic data from past time or estimate weather predictions. This also implies that the software can calculate general irrigation schedules for a crop. Exact calculations of real time irrigation schedules are not possible under current circumstances of field conditions.

A second difficulty emerges from the multiple constraints emerging from the circumstances under which farmers operate. They do configure the drivers of their behaviour. One illustration for such an external constraint is the power supply schedule by the local utility, which changed during the test period. Some farmers in the project area have constructed (with public subsidy) so called above field level "farm ponds" to store water which can be pumped into the pond during the night if electricity for pumping well or ground water is available then only. Irrigation could then take place during the day or by drip irrigation. This is a capital-intensive scheme only few farmers can afford.

A third barrier observed it that the software itself does not allow for automated import of data. The data has to be fed manually into the software. This part is a significant barrier to the application of this software on a larger scale, it seems nearly impossible to operate the software in an extension environment where the extension staff is exposed to multiple challenges as well and would need a quick and readymade tool. For this case other improved software with a similar methodology has to be developed. This should be implemented in a web based weather database. It should allow automated calculated water requirements for specific crops, on real time weather conditions, for each farm and plot. A weather forecast based on real conditions and historical information should be implemented as well. There should also be the possibility to adjust the current crop and field conditions and the availability of water and the effective applied irrigation water. But such kind of software can't be used as a single tool to make real-time irrigation advisories due to the difficulty of the complexity of the system. Field visits, soil moisture observations and farming experience can't be substituted by a single software operate from an office fare away. Furthermore the water availability over the season and for each farm is often unknown and makes it difficult do give irrigation advisories. The decision when to irrigate often depends on the availability of water and electricity. In the experiment it was obvious that the farmers to not accept al recommendations. It is questionable if they do it under other circumstances.

Another approach to improve the water use efficiency respectively the irrigation schedules is to teach the farmers how to estimate the water requirements on their own. The farmers should be empowered to make better irrigation decisions on their own. One easy to use method to estimate the soil moisture with low cost tools is the "Ribbon Method" (Estimating soil moisture by feel and appearance method). This methodology was tested by side this project. A tool was developed which allows the farmer to take soil samples from different depths and estimate the soil moisture by hand. The description of this method was made in a extra document (How to use the Ribbon method). Further more a crop chart for each crop, which describes the water requirement for each stage, and climate conditions, would be supportive for the farmers. With this, the farmers would be able to make their own improved irrigation schedules.