Bangladesh Metamodel

Water Demand Module

v1.0

- Draft -

1. Background

A significant component in modeling quantitative water resources in Bangladesh is the estimation of water demand for agricultural crop growth (evapotranspiration) and evaporation of water through other land uses. Water demand by agricultural crops (and other land uses) per (10-day) timestep is estimated, based on information of the detailed DRASS model, which is based on FAO CROPWAT method.

An important first step in the water demand module, is the determination of a static cropping pattern; the spatial allocation of agricultural crops over the different land types (F0 to F4) for each of the upazilas, based on crop suitability and district statistics (Agricultural yearbook, 2018). The crop water demand module is nested in the waterbalance module, that keeps track of water going in and out at field and soil level. The cropping pattern is also used by the agricultural production module, to estimate yield (losses) due to shortage or excess of water.

This note describes the allocation rules, to determine the cropping pattern, applied, as well as the formulas and values used to estimate crop water demand and for other land uses.

2. Purpose/Objective of the Module

The main objective of the Water Demand Module is:

"To estimate amount of water, needed to meet water loss through evapotranspiration from crop land, forest land, fallow land, settlements and permanent waterbodies."

Specific objectives are:

- Estimating crop water demand by crop by upazila.
- Estimating loss of water through evapotranspiration from forest land, fallow land, settlement and waterbodies by upazila.

3. Extent of Water Demand Module

The water demand module is developed each (BWDB)-project and non-project area per upazila on decadal (10-day) time step. It discerns 15 crops and 5 non-crop landuse categories. It is important to note that double- and triple-cropped areas are included.

4. Approach and Methodology

4.1 Approach

Following Approach has been followed for developing the water demand module:

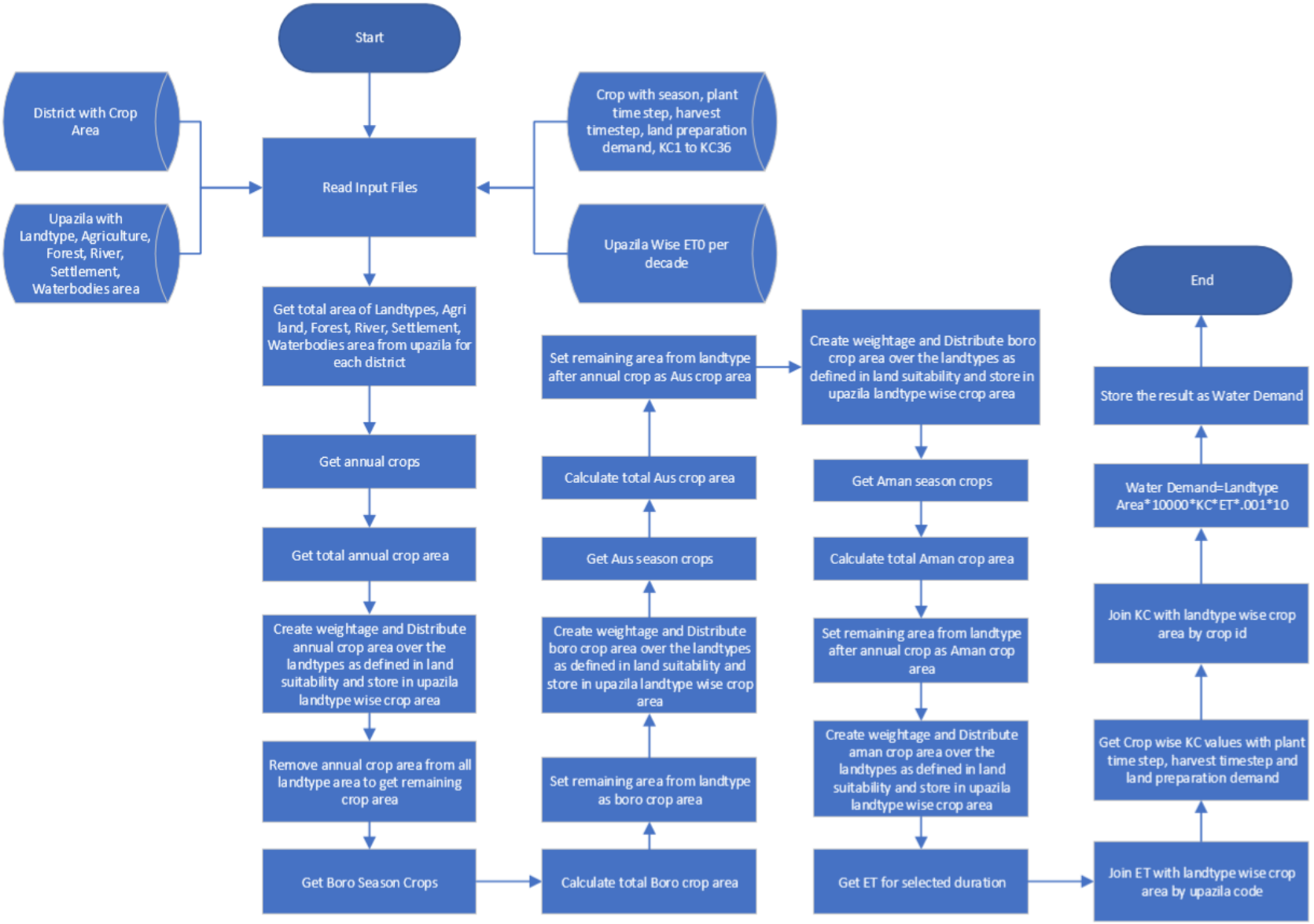

Figure 4.1: Approach of Development of Water Demand Module **(to be modified)**

4.2 Methodology

4.2.1 Definition of cropping patterns

A wide variety of crops is grown in Bangladesh. Among all the crops, rice is the most dominant crop because of its adaptability in diversified and ecological conditions prevailing in the country. Four varieties of rice crops which include Aus, T Aman, B Aman and Boro are grown in three crop growing seasons (pre-Kharif, Kharif and Rabi). In addition a number of non-rice crop types i,e.; wheat, pulses, maize, spices, oilseeds, vegetables, jute and sugarcane are included in the model and grown over the year.

It is not exactly recorded which crop is grown at which land type in which upazila. A cropping pattern per land type per upazila is deduced from district-wise statistics from the Yearbook of Agricultural Statistics - 2018 (BBS, 2019), an overlay with landtype (BARC) and landuse maps (CEGIS) and a set of simplified allocation rules.

1. Sugarcane (annual crop) is first allocated to single-cropped areas at each in the following order: F0, F1, F2, F3, F4;

2. Rabi crops are then allocated to remaining agricultural areas in the following landtype order: F0, F1, F2, F3, F4

3. Boro rice is then allocated to remaining agricultural areas, using an overlay of Boro rice area maps (from satellite images) and land types (BARC);

4. The remaining areas are allocated to Aus crops in the following landtype order: F1, F0, F2, F3 and F4;

5. Finally, the then remaining areas are allocated to Aman crops in the same order: F1, F0, F2, F3, F4.

The non-crop type areas are directly deduced from the GIS overlay between upazilas and land use maps.

In the Water demand module, crops from the yearbook are grouped according to following table:

SL	Crop Type	Season	Crop Name
1	Aus	Pre-kharif	Aus (Local), Aus (HYV)
2	T Aman	Kharif	Aman (LT), Aman (HYV)
3	B Aman	Kharif	B Aman
4	Boro	Rabi	Local Boro, HYV Boro, Hybrid Boro
5	Wheat	Rabi	Wheat
6	Pulses	Rabi	Arhar, Gram, Kheshari, Maskhalai, Motor, Mung, Mushur, Other pulses
7	Maize_Rabi	Rabi	Rabi Maize
8	Maize_Kharif	Pre-kharif	Kharif Maize
9	Jute	Pre-kharif	Jute
10	Spices	Rabi	Chilli_Kharif, Chilli_Rabi, Coriander, Garlic, Ginger, Onion, Turmeric
11	OilSeeds	Rabi	Castor, Groundnut, Linseed, Other Oil Seeds, Rape & Mustard, Till
12	Potato	Rabi	Local Potato, HYV Potato
13	Sugarcane	Annual	Sugarcane
14	Vegetables_S	Pre-kharif	Kharif Pumpkin, Kharif Brinjal, Patal Lady's Finger, Ridge Gourd (Jhinga), Bitter Gourd (Karolla), Arum (Kachu), Ash Gourd (Chalkumra), Cucumber, Long bean (Barbati), Indian Spinach (Puishak), Snake Gourd (Chichinga), Amaranth (Danta), Karala (Kakrol), Sponge Gourd (Dundul) Colocacia (Kachur Lati), Other kharif Vegetable
15	Vegetables_W	Rabi	Rabi Brinjal, Cauliflower, Cabbage, Gourd/Water Gourd, Rabi Pumpkin, Tamato, Radish, Bean, Bengal Spinach (Palong Shak), Red Amaranth (Lal Shak), Carrot, Laushak, Other Winter Vegetables

4.2.2 Crop Water Demand

The crop water demand is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

Land preparation requirement is the amount of water needed to saturate the soil for land preparation by puddling. Land preparation requirement have considered only for rice crops. Duration of land preparation is only the previous decade of transplanting date of rice. The total land preparation requirement for Aus and Boro crop is 175 mm each and for T Aman crop is 75 mm; based on review of available literature (Biswas 1987, EPC 1989, MPO 1987, Bangladesh Rice Knowledge Bank). Land preparation requirement has not been considered for B Aman rice as this crop is sown without puddling.

For estimating (crop) water demand (m3/dec), the following formula is used:

$CWD = (Et_{0,i} * length\ dec_i * Kc_i) / 1000 * (Acrop_i * 10000)$

Where

- CWD is crop water demand (m^3/decade)
- $ET_{0,i}$ is average reference evapotranspiration (mm/day) at i th decade
- Kc_i is the crop co-efficient at i th decade
- Acrop is Area of Crop (hectare) at i th decade following cropping pattern

Reference Evapotranspiration (ET_0)

Climatic data on temperature, humidity, wind speed and sunshine of the 36 BMD stations has been used for calculating ET_0. Decadal ET_0 has been calculated using the FAO suggested Penman-Monteith equation (FAO,1988). The stations data has been interpolated to upazila by using IDW (Inverse Distance Weighting) method.

Crop Co-efficient (Kc)

The Kc value is crop specific, and varies for a particular crop with the growth stages. The value is the highest during mid-season when the crops develop a maximum canopy and root system. The decade-wise Kc values for different crops grown in Bangladesh have been taken from the Technical Rport-2 (MPO,1987) and Crop Co-efficient report (BARI,2018). The decade-wise Kc values for different crops are presented in Table 1. Determining the evaporation by non-crop type are determined in a similar fashion.

Table 1: Crop co-efficient (Kc) of major crops

ID	Name	Season	Plant timestep	Harvest timestep	Decades starting from sowing or transplanting date of crop																
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Aus	2	13	21	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85									
2	T Aman	3	21	31	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85							
3	B Aman	3	21	31	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85							
4	Boro	1	3	14	1.10	1.10	1.10	1.10	1.11	1.15	1.22	1.29	1.29	1.22	1.10	0.85						
5	Wheat	1	33	7	0.45	0.57	0.74	0.94	1.07	1.13	1.15	1.12	1.03	0.88	0.50							
6	Pulses	1	32	6	0.46	0.61	0.85	1.04	1.10	1.10	1.10	1.00	0.80	0.60	0.40							
7	Maize_Rabi	1	31	9	0.87	0.87	0.87	1.12	1.12	1.12	1.20	1.20	1.20	0.87	0.87	0.87						
8	Maize_Kharif	2	13	27	0.45	0.45	0.45	0.87	0.87	0.87	1.12	1.12	1.12	1.20	1.20	1.20	0.87	0.87	0.87			
9	Jute	2	12	23	0.40	0.45	0.50	0.60	0.75	0.95	1.08	1.14	1.15	1.15	1.10	1.00						
10	Spices	1	35	8	0.40	0.45	0.65	0.85	0.90	0.95	0.95	0.90	0.85	0.80								
11	OilSeeds	1	31	3	0.46	0.61	0.85	1.04	1.10	1.10	1.10	1.00	0.80									
12	Potato	1	32	4	0.40	0.50	0.85	1.09	1.15	1.15	1.12	1.05	0.80									
14	Vegetables_S	2	13	24	0.42	0.42	0.80	0.80	0.80	1.30	1.30	1.30	1.30	0.93	0.93	0.93						
15	Vegetables_W	1	32	6	0.46	0.46	0.83	0.83	0.83	1.08	1.08	1.08	1.08	0.86	0.86							
	Decade				**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
13	Sugarcane	4	35	34	0.58	0.67	0.76	0.82	0.88	0.93	0.98	1.02	1.05	1.09	1.12	1.14	1.15	1.15	1.15	1.15	1.15	1.15
16	Forest	0	1	36	0.10	0.10	0.10	0.10	0.10	0.10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
17	Settlement	0	1	36	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
18	Bare_soil	0	1	36	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
19	River	0	1	36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	Waterbodies	0	1	36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Decade				**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
13	Sugarcane	4	35	34	1.15	1.15	1.15	1.15	1.15	1.15	1.14	1.13	1.11	1.07	1.02	0.93	0.80	0.68	0.57	0.46	0.40	0.47
16	Forest	0	1	36	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.10	0.10	0.10
17	Settlement	0	1	36	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
18	Bare_soil	0	1	36	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
19	River	0	1	36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	Waterbodies	0	1	36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Follow-up activities

1. BDP2100 scenarios and measures related to e.g. changing agricultural land use area, cropping patterns, introduction of new crop types, improved land management will be reflected in input of the water demand module (allocation rules and crop calendar (time of planting/harvesting and kc values)) and input of agricultural production module.

2. An Msc-thesis is formulated (April – September 2020) to test the sensitivity of cropping pattern and rotation to water resources and agricultural production in the Bangladesh metamodel. In addition, adaptation of farmers, making the cropping patterns more dynamic is further explored.

References

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