14th January, 2021

To

Shri Vikas Rastogi, IAS
Project Director,
Project on Climate Resilient Agriculture,
30B, Arcade, World Trade Centre,
Cuffe Parade, Mumbai, Maharashtra 400005

Dear Shri Rastogi,

Thank you very much for the review by Prof. Sekhar Muddu. It was very useful and we will respond to it point by point.

1. **Hourly model - an improvement.** The hourly model is indeed much better in matching with (i) the field experience, (ii) field level validation at selected catchments, and (iii) computed post-monsoon indices for a selection of villages which indicate correct estimation of water availability for Rabi crops. This will also be a part of our Phase IV reports.

2. **Field Validation.** Field validation was done in 3 catchments for this year. The results indicate a very good match with the model. Some new phenomena were observed - water-logging and ponding to cite two. These also indicated that better farm preparations make a substantial impact.

   We agree with Prof. Muddu that more field studies are required, esp. since this was an excess monsoon year and some key phenomena may have been missed. The exact methodology for the study has been documented in Phase III. This may be replicated and extended by the agencies chosen to conduct the study. It must be noted that the COVID-19 epidemic and lock-downs presented severe challenges in almost all parts of the field work.

   The closure report will be presented in Phase IV. We recommend 6 more studies in a variety of agro-climatic regions of Maharashtra.

3. Stream Flow and other improvements in the model. We have proposed 3 key improvements, viz., modelling of Ponding, incorporation of Aquifer Depth and Specific Yield, and Stream Flows as an application of a broader data structure called "Regional Geography". This provides an IT framework which allows the analysis of administrative and hydrological boundaries and allows for convenient modelling of on-land flow, stream flow and the first steps towards base flows and groundwater flows.

Again, the incorporation of these need expert advice and incorporation of these into the validation studies. The stream flow model was not used in the field study. It will be used in the command area case study which will be presented in Phase V, since the phenomena are related to recharge through canal networks.

4. **GSDA and IITB**. The point that the IITB model computes "potential recharge" is correct. Time lags and intervening lateral flows complicate the materialization of the potential recharge into actual recharge. Besides this, there are other factors such as soil-saturation (modelled) and water-logging due to full aquifer (recommended to be modelled).

   As we have indicated, the data on the current 28 studies is patchy in parts and sparse. It does not allow us to solve the above riddle. The suggestion that GSDA should do a study of a few smaller catchments (as in our studies reported above) and gather data at a smaller time steps, is extremely important. This will serve the purpose of refining both the GSDA accounting methods and the IITB model.

   Coming to irrigation water applied, we are indeed using the GSDA estimate of extraction to cross-check our computation of total water available, with the obvious check that water extracted (as reported by GSDA) should be less than our estimate of total water available. There again, the cropping pattern, as used by GSDA, matches the micro-planning data in some clusters but not in others. Rationing in Rabi is widespread and this is evident from the wide variety of yields seen for most crops. This has been presented in earlier reports.

5. **NBSS&LUP data.** Soil shapefiles were provided by the NBSS for a few clusters from Amravati, Jalna, Hingoli, Washim district etc. These shapefiles were based upon the field experience of the experts. Laboratory testing of the field samples collected and the integration of results was pending. Detailed report on comparison of water balance results using NBSS and MRSAC soil data for Bajar Wahegaon and Malegaon clusters (Jalna) has been already submitted to PMU.
   As per our field experience with the NBSS layers in Washim and Hingoli, we found that in some places the MRSAC data matched the field observations better, while in other locations, the NBSS layer was better. This may change in the updated soil data to be received from NBSS.

Other points:

(i) Page 8. This is indeed the soil depth reported in the data. Such soil depths are routinely observed in farmer fields as well.

(ii) ET0 range. The 2mm-10mm is the range obtained from the Penman-Monteith model for the field conditions. There are several days of extremely high temperatures. On the other point of run-off, with a 900mm of rain, the total infiltration can hardly be more than 500mm.

But also see the impact of farm-preparation, e.g., ponding. This has been recommended as the next step in modelling.

(iii) The IITB model computes water budget components at point-level and then aggregates them at village level using a given cropping pattern. The model is run for the monsoon season only and hence cotton, bajra and soybean appear in the results table.

(iv) The term PET is used for crop-ET. This was used in the first year and it was decided not to change it since people in the field are now more familiar with this term. ET0 is as in technical literature and is crop-independent. Soil moisture in wastelands will depend on soil thickness. This is as per data.

(v) Run-off estimation: Part of the gap in the estimates is because of different rainfall considered. GSDA has followed Strange's table (which is known for its conservative estimates) at 75% dependable rainfall of average annual rainfall whereas IITB has used actual daily/hourly rainfall and the variation in runoff mainly depends on occurrence of peak rainfall events and dry spells.

(vi) Some assumptions used in specific yield computation using GEC norms were found to be problematic, which may lead to significant deviation in specific yield values which are crucial in estimating groundwater recharge through Water-Table-Fluctuation method rather than through conservation equations. Given this, we cannot use this for calibration of the IITB model. We have used actual field measurements and other procedures to validate our model. From our field experience, GSDA has underestimated the number of wells and overestimated unit well draft.

Lastly, our field methodology roughly follows what Prof. Muddu has indicated.

With Regards,

Milind Sohoni
IIT Bombay

Review report of Phase-III Part A report submitted by IIT Bombay for the PoCRA project.

The Phase III Part A report of IIT Bombay for the PoCRA project deals with validation of model developed by IIT Bombay, on-field measurements and improvements & perspectives. This report is focused on "Refinement and further development of Water Balance framework" continuing from the Phase I & II studies pertaining to the development, analyses and implementation of the IITB water budget model for the PoCRA villages.

The following are the review observations for the items of the reported Phase III study:

1. Refinements are made to the IITB water budget model to use a higher temporal resolution (i.e. hourly time step) with an aim to improve model simulations of hydrology components in the model by using input rain intensity data at hourly scale. This refinement is justified as in small watersheds the storm runoff is important and dealing with rainfall intensity inputs at hourly scale is definitely an improvement for the runoff module.

2. The validation of the refined model using the runoff measurements required installation of water level sensors. For this purpose, six catchments in the three PoCRA clusters were selected for carrying out runoff measurements. Stage-discharge relationships for each of the catchment outlets were made using runoff generated for one monsoon season.
   It is reported that the field team carrying out the runoff measurements had faced some challenges as expected in the first season of monitoring. Hence the data set can be termed preliminary and furthermore since the coverage is across a few storm flows during one monsoon season, the stage-discharge relationships generated will not be exhaustive. Even though, the comparisons using hourly and daily model of runoff is made with the preliminary measured data, it is required and critical to do such a comparison for a few monsoon seasons in the coming years and atleast for the next year (i.e monsoon season of 2021) to assess in the first step that if the performance of modeled runoff at these sites compare well (i.e. good RMSE) with the measured runoff, and in addition in the second step to assess if the runoff using hourly time step is superior to the model with a daily step.

3. Improvements were made to the Stream flow model to account for transmission losses and recharge occurring within the farms before the runoff reaches the outlet. A framework was developed for accounting these losses at farm scale and preliminary trial simulations were performed in two clusters.
   Incorporating the physics of conveying and recharge losses is an important step in the model. However, for testing it is important that the simulations are to be performed in the catchments, which have field runoff measurements to evaluate and validate the impact of the losses formulated in the model. It was not clear from the reported study, if the trial analyses that were performed, were in the catchments that were being gauged and how the variations, if any, among the monitored catchments.

4. Incorporation of GSDA recharge into IITB model: Analyses have been performed by IITB using the water budget model in 28 clusters for which GSDA has carried analyses of recharge and draft estimation using GEC methodology that involved well inventory, measurement of ground water levels in a network of the wells, survey of

groundwater extraction in monsoon & non-monsoon months and return flows from irrigation and storage structures. Comparison of recharge estimated by dynamic model of IITB with the lumped assessment of GSDA was performed.

It is reported that the recharge from both GSDA method and IITB model have shown significant deviations. It may be noted that this would be an expected outcome in the first instance. The GSDA recharge is a lumped annual recharge at the watershed scale, while the IITB model produces a dynamic hourly/daily recharge at desired spatial scale. Moreover, the GSDA approach estimate of recharge is based on the seasonal water level fluctuations in the well network, while the recharge estimated from IITB model is from the recharge leaving the bottom of the soil horizon (as the model is adapted from SWAT framework) and could be termed as "potential recharge". Significantly the recharge estimated by both the approaches are not at the same depth i.e. one at the bottom of the soil horizon, which is say about 1m below ground level while the other recharge is at the ground water table, which is perhaps few tens of meters below ground level and hence the two quantities necessarily need not be the same. There could be several other significant aspects in groundwater recharge at the water table such as lateral groundwater flows from and to the neighboring catchments, while the soil-water budget model for recharge is essentially a vertical flux. Hence, it may be worthwhile to investigate/assess the bias if any of the annual recharge from both approaches among the 28 clusters. Further, if GSDA approach could be applied for smaller units within the watershed of few clusters, then there is an opportunity to assess spatial variation of recharge from GSDA and assess the same with that of the IITB model. In addition, if a groundwater model based approach is used with the GSDA data set, then one could obtain monthly recharge in few spatial land units within a watershed and this could be useful to assess/verify if the IITB model has similar patterns at monthly scale in the spatial units. It is my belief that the recharge estimates at monthly scale at spatial land unit scale are compared within a watershed to reconcile the approaches based on groundwater budget and soil-water budget. The other useful input to IITB model is the amount of irrigation application. Since the GSDA method provides draft estimate, this needs to be tied up to the IITB water budget model. I somehow could not see the discussion related to this aspect in the trial studies reported.

5. It is reported that the IITB team is provided with improved soil maps at 1:10000 scale for 8 clusters by NBSS&LUP and the study reports that simulations were performed using IITB model in these clusters. It is not clear from the reported observations, of the water budget model outputs using the soil maps at both the scales i.e. MSRSAC maps and those of NBSS&LUP maps. If this attempt is performed on the clusters combining data sets from GSDA and NSBSS&LUP, and data analytics performed with sensitivity studies, it would be help to track the output results due to the additional inputs in comparison to the Phase-1 results of IITB model.

Specific Comments:

P8 : Soil total depth = 25 cm... only this small ???
P10 onwards : range of ETo (with all methods is quite large) = from 2 to 10 mm/day
10mm is a lot ! And it never goes below 2mm... don't they ever have cold cloudy days ?
P13 onwards : water balances : biggest component is runoff in most cases !!! (often more than 50% of the rain !!!)

QGIS plugin
P49 : not really understood how they compute "villages". Cotton, bajra, soybean ... All rainfed crops ?
Not understood : what is PET? P53, they write : "This calculated ET0 is further used to compute PET" ???
Ok, wasteland has more GW recharge... but more soil moisture ??? how come ?

Runoff estimation :
one cannot compare GSDA's estimate (average runoff that can be harvested) and IITB calculation (dynamic yearly)
Yet, this doesn't explain the discrepancy: several hundreds of mm for IITB, 60mm for GSDA. and several hundreds is A LOT !

Groundwater:
- most issues noted by IITB - if correctly identified, are indeed highly problematic (deviations from GEC method, data issues).
one point though : - according to IITB, draft estimation by GSDA => possibly of number of wells pumping is underestimated - This would lead to an underestimate of recharge -
While GSDA is already giving much more recharge than IITB

For the plan, it looks correct to me :
- calculate GW balance based on primary data measured by IITB and GSDA (see my observations in item # 4 above)
- measuring runoff (it can tedious work) !
- accounting for ponding in fields (which will decrease significantly stream runoff in the model)
- accounting for baseflow (lucky, to see nice GW baseflow !)

(Prof. Sekhar MUDDU)