Original Research Article

Calibration and validation of DSSAT CROPGRO Peanut model for yield and yield attributing characters of groundnut varieties in Northern Agro-Climatic zone of Tamil Nadu

ABSTRACT

Aim: The research study was conducted to calibrate and validate the DSSAT CROPGRO peanut model for simulating the potential yield of groundnut to deciding the best possible management options at major growing areas of Northern Agro-Climatic zone of Tamil Nadu.

Study Design: The experiment was conducted in Split plot Design with four Sowing dates and cultivars.

Methodology: The DSSAT model requires layer wise soil data (physical and chemical), including soil texture and other soil properties. Daily weather data, including maximum and minimum air temperature (°C), solar radiation (MJ m^{-2} day^{-1}), Relative Humidity (%) and precipitation (mm) were used as inputs. Data describing management practices and information on cultivar-specific genetic coefficients were used to calibrate the model. Validation of model were carried out using observed growth and yield attributes of TMV13 and G7 varieties using RMSE, NRMSE (it is better to mention the full form of the abbreviation within parenthesis in the first place of its use) and agreement per cent as test criteria for the evaluation.

Results: The performance of DSSAT CROPGRO peanut model for simulated growth attributes were underestimated the growth attributes like days to anthesis, leaf area index, days to first pod and days to maturity than compared to observed growth attributes of TMV13 and G7 varieties. But the model performs better for G7 as compared to TMV13. Whereas, yield and yield attributes of CROPGRO peanut model were overestimated than the observed yield.

Conclusion: The simulation model shows the low RMSE, NRMSE and high agreement per cent for growth and yield of groundnut which was more than 90 per cent, it shows the higher level of confidence on model simulation with observed characters.

***Key words**: DSSAT, CROPGRO, Groundnut, Yield, Simulation model*

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crops grown in subtropical and tropical regions of the world. India occupied the second position in acreage and production of groundnut with an area of 4.73 million hectares and a production of 6.93 million tonnes during 2018-19 (Directorate of Economics and Statistics, 2020). The average productivity was 1465 kg ha^{-1}. Seventy per cent of the groundnut area and production is concentrated in the four states *viz*., Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka. In Tamil Nadu, it is the major oilseed crop grown under rainfed and irrigated condition accounting for 5.7% of the total cropped area. Groundnut is grown in an area of 3.35 lakh hectares with a production of 9.11 lakh tonnes during 2018-19 in the state. The average productivity was 2725 kg ha^{-1} (Directorate of Economics and Statistics, 2020). The districts *viz*., Tiruvannamalai, Vellore, Villupuram, Namakkal, Erode and Salem constituted 54.9% of the area under groundnut in Tamilnadu (Season and Crop report, 2018). Weather is one of the important factors, which affects all stages of groundnut growth and finally the yield (Bandyopadhyay *et al.,* 2005). Owing to variation in monsoon rains, peanut production fluctuates in major growing areas.

Simulation models are useful tools in deciding the best possible management options for optimum growth and yield of any crop against available climatic variables along with soil and water inputs (Parmer et al., 2013 and Yadav et al., 2012). Use of these models are gaining importance particularly against the present climatic change scenario. Improved production technology at the farm level is the most crucial starting point for improving the productivity of groundnut in future by employing and appropriately adapting suitable crop growth simulation models (Anothai et al., 2008). In addition to this, the use of crop yield simulation models comes handy to the government agencies, trade and industry for planning, distribution, storage; processing and export/import of crop produce besides taking timely policy decisions on fixing levy prices provide a reliably accurate advance estimation of yields. Crop simulation models are recent tools that can facilitate identification of production constraints and assist in agro-technology transfer (Naab et al.,2004; Dangthaisong et al.,2006 and Putto et al.,2009).

Models are widely used as a management tool to evaluate the effects of climate, soil, hydrologic and agronomic factors on crop yield and its variability (Khan et al., 2009). It is not unlikely that use of crop simulation model will definitely improve agronomic weather information and interpretation in time to come and farmers will be able to reduce production risks and increase crop yield by tailoring management decisions to current and expected weather.

The Cropping System Model (CSM)-CROPGRO-Peanut is a process-oriented model that is part of the Decision Support System for Agrotechnology Transfer (DSSAT) (Hooenboom et al., 2010). The model has been evaluated extensively for investigating multiple environmental conditions and evaluating crop yield, cultivars, cropping practices and genetic coefficient (Boote *et al.,* 1985). Accordingly, the validated model can be used to predict growth and yield responses to sowing dates, nutrients, row spacing, and irrigation. The objective of the present study was to evaluate the performance of the model for peanut crops grown in northern agro-climatic zones of Tamil Nadu and.(????)

2. MATERIALS AND METHODS

The groundnut field experiment for the calibration CROPGRO peanut was conducted in *Kharif* season during July to November 2019 at the farm of Oilseeds Research Station, Tamil Nadu Agricultural University, Tindivanam. The Farm is located in the Northern agro climatic zone of Tamil Nadu at 12.5^o N latitude, 79.5^o E longitude and at an altitude of 46 m above mean sea level (Figure 1). The growth and yield data collected from the experiments were used to calibrate and validate the DSSAT CROPGRO-Peanut model. In the field experiments, eight treatment combinations, including four planting dates (July 1 and 16, August 1 and 16) and two ruling varieties (TMV 13 and G7) respectively, were used and replicated three times, with plot sizes of 20 square meters. The whole experiment was designed following the split-plot technique with main factor of sowing date and subfactor as groundnut varieties. Groundnut seeds of all the varieties were sown at a depth of 5 cm with 30 cm row-to-row and 10 cm plant-to-plant spacing and all other package of practices were adopted as TNAU crop production guide recommendations.

2.1. Model description

2.1.1. CROPGRO-Peanut model (sub sub-heading should be underlined, reduce the font size; check the journal's format)

The DSSAT CROPGRO-Peanut model v 4.7 was used to study the effect of sowing dates with respect popular cultivars on yield and yield parameters of peanut and to identify a suitable management strategy to cope with possible climate changes in Northern agro climatic zone of Tamil Nadu. The four sowing dates and two varieties combinations were employed to fit the model to changing scenarios. The model requires layer wise soil data (physical and chemical), including soil texture and other soil properties. Daily weather data, including maximum and minimum air temperature (°C), solar radiation (MJ m^{-2} day^{-1}), Relative Humidity (%) and precipitation (mm) were used as inputs. Data describing management practices and information on cultivar-specific genetic coefficients were used to calibrate the model. The genotype data file contains genetic coefficient data, namely the genetic coefficient, which describe specific cultivar characteristics of peanut. The CROPGRO-Peanut model uses 18 genetic coefficients to define development and growth characteristics of a peanut cultivar were presented in Table 1.

2.1.2. Model calibration

The calibration of the CROPGRO-Peanut model was based on yield and yield components *viz.*, pod yield, number of pods and dry matter production data were recorded at the time of harvesting. The genetic coefficients of the peanut cultivars that affect the phenological stages in the CROPGRO models were derived using the "trial-and-error" method of DSSAT v 4.5. Adjustment was performed to match the observed crop phenology and yield with the simulated values and to make the calibrated genetic coefficient lie within the predefined error limits for the cultivar. Following this method, all coefficients were optimized for further simulation (Table 1). For calibration, information for key phenological events (anthesis day, LAI, first pod day, days to maturity), and yield-related data including pod yield, haulm yield and HI (mention the full form in the first place of its used) were used. The model simulation was accordingly started with the default values available in the model for similar soils of other regions. Details of the experiment, data collection and model calibration are described by Banterng et al. (2003) and Suriharan et al. (2006). Flow chart depicting the methodology of DSSAT CROPGRO Peanut crop simulation model were presented in the Figure 2.

The performance of the CROPGRO-Peanut model was evaluated using the dataset from the field experiments. This approach can be considered as a true validation of the model, as the model parameters were not calibrated on the basis of the field experiment dataset. All the simulated and observed yield and yield components were compared and presented.

2.2. **Test criteria for evaluation**

An analysis of the degree of coincidence between simulated and observed values was carried out by using R^2, Root Mean Square Error (RMSE), Normalised Root Mean Square Error (NRMSE) and Agreement percent (Jemison *et al.*, 1994). [Not mentioned in Reference section, please check that]

$$RMSE = \sqrt{1/N \sum (Oi - Pi)2}$$

$$NRMSE = 100 \times (RMSE / O_i)$$

$$Agreement\ (\%) = 100 \times (1 - (RMSE / O_i))$$

Where P*i* and O*i* were the predicted and observed values for the observation, and N was the number of observations within each treatment. RMSE was measure of the deviation of the simulated from the measured values, and was always positive. A zero value was ideal. The lower the value of RMSE, the higher was the accuracy of the model prediction.

3. RESULTS AND DISCUSSION

3.1. Growth attributes

3.1.1. Days to Anthesis **(check the sub sub-heading format from journal's guidelines)**

The observed days to anthesis for two cultivars like TMV13 and G7 was 30 and 27 days respectively, whereas model simulated days to anthesis was 27 and 26 days. The test criteria computed by RMSE, NRMSE and Agreement percent for two cultivars are 3, 1, 10 and 3.70, 90.00, 96.30 per cent, respectively and presented in Table 2. It suggested that the model performance was better for G7 variety as compared to TMV7 (check the name) for simulation of days to anthesis. The findings were conformity with the results of Ujinwal and Patel (2008) [Not included in Reference section, check that]and Akula (2003) days to maturity and the model were underestimate the days to anthesis than observed days.

3.1.2. Leaf Area Index (LAI)

The observed LAI of the two varieties like TMVB (check the name) and G7 were 5.72 and 6.10, respectively whereas DSSAT CROPGRO peanut model simulated LAI was 5.32 and 5.70, respectively for the two varieties. In terms of LAI, G7 variety performed better as compared to TMV13 with respective to the RMSE, NRMSE and Agreement percent (Table 2). Thus, the model under estimate the LAI than compared to observed data. The results of Leaf Area Index of groundnut simulated by CROPGRO peanut model was in conformity with the finding of Parmer et al. (2013) and Babu (2006).

*3.1.3. **Days to First Pod and maturity***

The days to first pod formation and days to maturity for the two varieties like TMV13 and G7 was underestimated the CROPGRO peanut model than the observed data. The test criteria for two cultivars TMV13 and G7 (Table 2) suggested that model performance was better for G7 as compared to TMV13 variety for days to pod development whereas TMV 13 performed better than G7 for days to maturity. The similar results were found by Pandey et al. (2001) and Deiveegan and Pazhanivelan (2016).

3.2. Groundnut pod and haulm yield

The performance of the model in simulating the pod yield was overestimated than the observed groundnut yield. The pod yield of groundnut for G7 was better performed than TMV13 in CROPGRO peanut model and test criteria of the model was in good confidence level. The test criteria like RMSE, NRMSE and agreement per cent for evaluating pod yield of TMV13 was 264, 8.44 and 90.20, respectively whereas, 121, 3.85 and 96.15, respectively for G7 variety (Table 2). The findings were in conformity with the results of Parmer et al. (2013); Soler et al. (2007) and Yadav et al. (2012).

The observed haulm yield of the two varieties like TMVB (check the name) and G7 was 5892 and 6536 (mention the unit), respectively whereas DSSAT CROPGRO peanut model simulated haulm yield was 6389 and 6874 kg/ha, respectively for the two varieties. In terms of haulm yield, G7 variety performed better as compared to TMV13 with respective to the RMSE, NRMSE and Agreement percent (Table 2). Thus, the model overestimates the haulm yield than compared to observed data. The results of haulm yield of groundnut simulated by CROPGRO peanut model was in conformity with the findings of Babu (2006) and Sabarinathan et al. (2020).

Results showed that the values of simulated harvest index were found to have been underestimated when compared with corresponding observed values. The average errors as computed by RMSE, NRMSE and agreement percent were 0.014, 4.39 and 95.61, respectively for TMV13 whereas 0.018, 5.27 and 94.73, respectively (please compare and check the values mentioned in Table 2) .

4. CONCLUSION

In the simulation model, days to anthesis, LAI, days to fist pod development, days to maturity, pod yield, haulm yield and harvest index were satisfactorily simulated by CROPGRO peanut model, pod and haulm yield were overestimated and rest of the parameters under estimated by the model with higher agreement percent of more than 90 with low RMSE and NRMSE values. DSSAT CROPGRO peanut model has proved to be valuable tool and effective model to predicting groundnut yield. Therefore, the validated DSSAT model can be further used for applications such as prediction of crop growth, phenology, water management, potential and actual yields, performance of groundnut under climate variability and change scenarios etc. The model may also be used to improve and evaluate the current practices of groundnut growth management to achieve enhanced groundnut production.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country.

There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

24
24

Akula, B. (2003). Estimating wheat yields in Gujarat using WTGROWS and INFOCROP model. Ph.D. (Agri. Meteorology) thesis submitted to GAU, Sardar krushinagar.

Anothai, J., Patanothai, A., Jogloy, S., Pannangpetch, K., Boote, K.J. and G. Hoogenboom. 2008. A sequential approach for determining the cultivar coefficients of peanut lines using end-of-season data of crop performance trials. Field Crops Research, 108(2): 169-178.

Babu, S. (2006). Validation of CROPGRO model for growth, development and yield of rainfed groundnut in South Saurashtra agroclimatic zone of Gujarat. M.Sc. thesis submitted to GAU, Junagadh.

Bandyopadhyay, P.K., S. Mallick, S.K. Rana. 2005. Water balance andcrop coefficients of summer-grown peanut (Arachis hypogaeaL.) in a humid tropical region of India, Irrig. Sci. 23, 161–169.

Banterng, P., A. Patanothai, K. Pannagpetch, S. Jogly, G. Hoogenboom,2003. Seasonal variation in the dynamic growth anddevelopment traits of peanut lines, J. Agric. Sci. (Camb.) 141, 51–62.

Boote,K.J., J.W. Jones, J.W. Mishoe, G.G. Wilkerson, Modeling growth and yield of groundnut, Agrometeorology of Groundnut, Proceedings of an International Symposium, ICRISAT Sahelian Center, Niamey, Niger, August 21–26, 1985, Patancheru, AP, India 1986, pp. 243–254.

Dangthaisong, P., Banterng, P., Jogloy, S., Vorasoot, N., Patanothai, A., Hoogenboom, G., 2006. Evaluation of the CSM-CROPGRO-peanut model in simulating responses of two peanut cultivars to different moisture regimes. Asian J. Plant Sci. 5, 913–922.

Deiveegan, M. and S. Pazhanivelan. 2016. Modeling Groundnut (Arachis hypogea) Yield at Spatial Level in Tiruvannamalai and Villupuram Districts by Using DSSAT Crop Simulation Model. *Advances in Life Sciences,* 5(17), Print : ISSN 2278-3849, 6863-6867.

Directorate of Economics and Statistics (DES). 2020. Agricultural statistics at a glance. Dept of Agric. and Co-operation. Ministry of Agriculture, Government of India. Available online: http://eands.dacnet.nic.in.

Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, K.J. Boote, L.A. Hunt, U. Singh, J.L. Lizaso, J.W. White, O. Uryasev, F.S. Royce, R. Ogoshi, A.J. Gijsman, and G.Y. Tsuji. 2010. Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5 [CD-ROM]. University of Hawaii, Honolulu, Hawaii.

Khan, N., M.I. Uddin Faridullah, Agronomic characters ofgroundnut (Arachis hypogeaeL.) genotypes affected bynitrogen and phosphorus fertilization under rainfedcondition, Electron. J. Environ. Agric. Food Chem. (2009)61–68.

Naab, J.B., Singh, P., Boote, K.J., Jones, J.W., Marfo, K.O., 2004. Using the CROPGROpeanut model to quantify yield gaps of peanut in the Guinean Savanna zone of Ghana. Agron. J. 96, 1231–1242.

Pandey.V, Shekh, A.M., Vadodaria, R.P. and Bhat, B.K. (2001). Evaluation of CROPGROPeanut model for two genotypes under different environment. Paper presented at the National seminar on Agro Meteorological Research for Sustainable Agricultural Production at G.A.U. Anand.

Parmar, P. K., H.R. Patel, S.B. Yadav and V. Pandey. 2013. Calibration and validation of DSSAT model for Kharif groundnut in north-Saurashtra agro-climatic zone of Gujarat. J. of Agromet., 15 (1): 62-65.

Putto, C., A. Patanothai, S. Jogloy, K. Pannangpetch, K.J. Boote,G. Hoogenboom, Determination of efficient test sites forevaluation of peanut breeding lines using the CSM CROPGROpeanut model, Field Crop Res. 110 (2009) 272–281.

Sabarinathan, B., S Pazhanivelan, KP Ragunath, AP Sivamurugan and NS Sudarmanian. 2020. Calibration and validation of CERES-sorghum module of DSSAT model for rabi sorghum under rainfed condition, Pharma Innovation, 10 (1), 715-718.

Season and crop report of Tamilnadu . 2018. Department of economics and statistics, Chennai, Tamilnadu.

Soler, C. M. T.; Sentelhas, P. C. and Hoogenboom, G. 2013. Application of the CSM-CERES-Maize model for planting date evaluation and yield forecasting for maize grown off-season in a subtropical environment. Eur. J. of Agron. doi:10.1016/j.eja.2007.03.002. [check the year and do the correction]

Suriharan, B.A. PAtanothai, K. Pannangpetch, S. Jogloy and G. Hoogenboom. 2006. Derivation of cultivar coefficients of peanut lines for breeding applications of the CSM-CROPGRO peanut model. *Crop Science. 44, 165-172.*

Yadav,S.B., H. R. Patel, G. G. Patel, M. M. Lunagaria,B.I.Karande,A.V.Shah and V. Pandey. 2012. Calibration and validation of PNUTGRO (DSSAT v4.5) model for yield and yield attributing characters of kharif groundnut cultivars in middle Gujarat region. *Journal of Agrometeorology* [ISSN: 0972-1665], 14, (24-29).

Reference section needs proper correction as it was not written as per the journal's format and two references were not included in this section as well (highlighted in the text).

References mentioned in the text should be written by following the journal's guidelines.

Table 1. Genetic Co-efficient of TMV13 and G7 for CROPGRO Peanut model

Sl. No.	Code	Description	TMV13	G7
1	CSDL	Critical Short Day Length below which reproductive development progresses with no daylength effect (for shortday plants) (hour)	11.84	11.84
2	PPSEN	Slope of the relative response of development to photoperiod with time (positive for shortday plants) (1/hour)	0.00	0.00
3	EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)	18.5	19.3
4	FL-SH	Time between first flower and first pod (R3) (photothermal days)	7.3	7.9
5	FL-SD	Time between first flower and first seed (R5) (photothermal days)	17.5	18.7
6	SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	62.20	61.30
7	FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)	70.50	69.50
8	LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO2, and high light (mg CO2/m2-s)	1.15	1.25
9	SLAVR	Specific leaf area of cultivar under standard growth conditions (cm2/g)	250.00	245.00
10	SIZLF	Maximum size of full leaf (three leaflets) (cm2)	17.30	16.90
11	XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	0.75	0.70
12	WTPSD	Maximum weight per seed (g)	0.371	0.410
13	SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	33.00	33.00
14	SDPDV	Average seed per pod under standard growing conditions (#/pod)	1.65	1.65
15	PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	19.20	19.00
16	THRSH	The maximum ratio of (seed/(seed+shell)) at maturity.	74.00	74.00
17	SDPRO	Fraction protein in seeds (g(protein)/g(seed))	0.270	0.270
18	SDLIP	Fraction oil in seeds (g(oil)/g(seed))	0.514	0.480

Table 2. Test criteria for evaluation of the model for groundnut growth and yield attributes

	Simulated Data		Observed Data		RMSE		NRMSE		Agreement	
	TMV 13	G7	TMV13	G7	TMV 13	G7	TMV13	G7	TMV 13	G7
Days to Anthesis	27	26	30	27	3	1	10	3.7	90	96.3
Leaf Area Index	5.32	5.7	5.72	6.1	0.4	0.4	6.99	6.56	93.01	93.44
Days to First Pod	38	39	42	42	4	3	9.52	7.14	90.48	92.86
Days to Maturity	103	101	108	109	5	8	4.63	7.34	95.37	92.66
Haulm Yield	6389	6874	5892	6536	497	338	8.44	5.17	91.56	94.83
Pod Yield	2958	3266	2694	3145	264	121	9.8	3.85	90.2	96.15
Harvest Index	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28

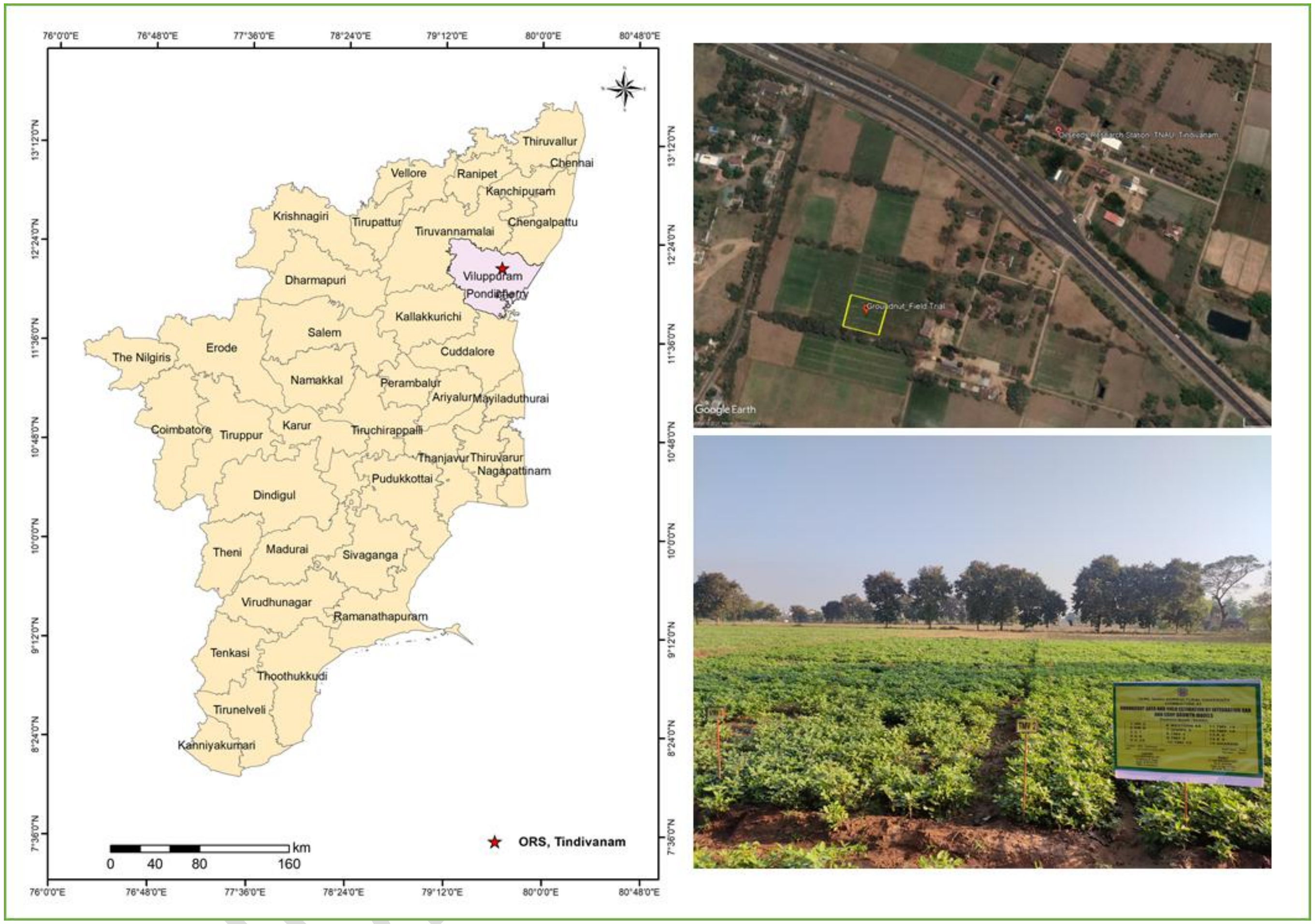

Figure 1. Location Map of field experiment

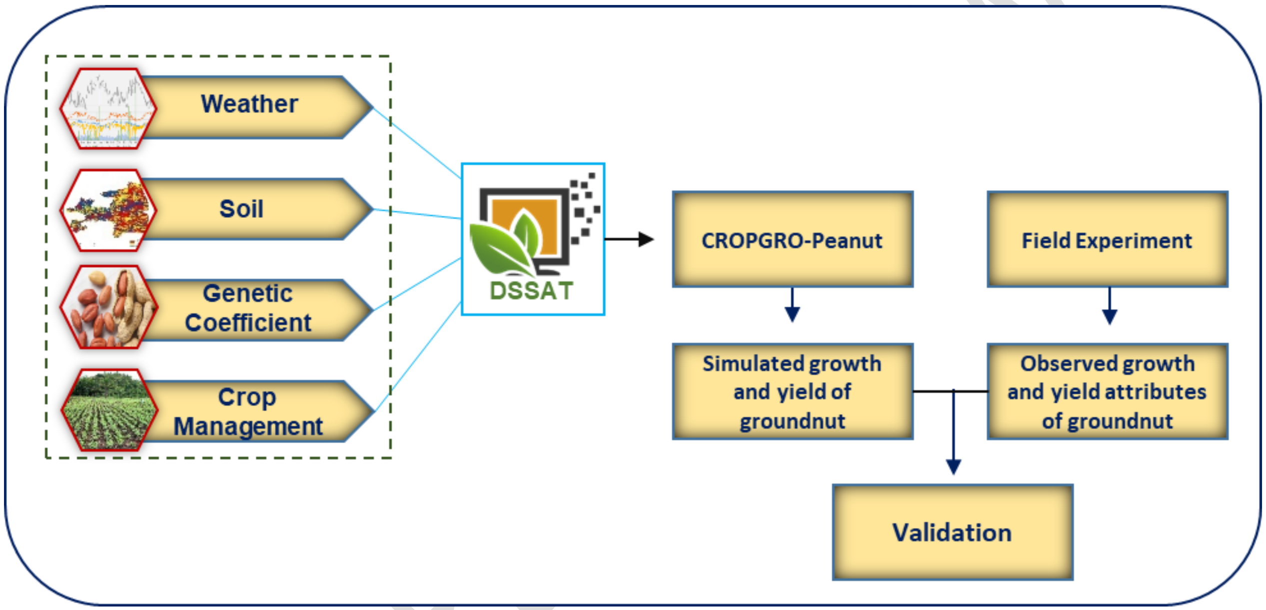

Figure 2. Flow chart depicting the methodology of DSSAT CROPGRO Peanut crop simulation model