Model-based approach to quantify and regionalize peanut production in the major peanut production provinces in the People's Republic of China

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Abstract: China is the largest peanut producer in the world and peanut therefore an essential economic product earning significant income for China's farmers. Major provinces for peanut production are located in the middle and eastern provinces. In these regions, drought stress between germination and pod setting, could be severe and yield decline because of uneven rainfall and climate variability. Four provinces were selected for modeling and simulating large area yield estimation in order to evaluate potential yield with respect to average rainfall in the individual regions. Measured, average yield during the evaluated years ranged from 2918 kg ha^{-1} to 3969 kg ha^{-1} with a mean yield of 3420 kg ha^{-1} and a mean modeled yield of 3422 kg ha^{-1}. The model showed a good fit between observed and simulated data with a RMSE of 252. Model error was 7.4 %.

1 Introduction

Concerning peanut and peanut production, China speaks in superlatives. With more than 290 000 t shelled and unshelled peanuts in 2007, the country is the largest peanut exporter in the world according to the FAO with one third of the world market share [Ch09]. China has one fifths of the world area under peanut and it produces more than two fifths of the total world peanut production [Ga04]. In addition, peanut is the major oilseed crop in China making 40 % of the land's total oilseed production and 25 % of the cropped area [Ga96]. Hence, peanut is an essential economic product for the country. Since the foundation of the PR China, more than 200 varieties have been bred and more than 80 have been introduced and used [Ga96] showing the importance of the crop. Approximately 70 % of the production takes place in five provinces [Ga04] with Shandong, Henan and Hebei on top. Seven agro ecological zones are determined with peanut production predominant in the Chinese middle and eastern provinces. Highest yields and the largest area under peanut production are achieved in Shandong and Henan province, both part of the North China Plain.

Generally one crop or three crops per two years are grown in these regions with peanut usually being intercropped with wheat, maize, bean or sweet potato. Since the 1980's, when improved management practices like the polythene mulching and improved varieties have been introduced, peanut yield increased steadily [Ga04] [Ga96].

Nevertheless, there are constraints about substantial yield gaps [JN96] between yields realized by farmers and those recorded from research stations or potential yield estimations. Yield fluctuates strongly due to climate variation and uneven adoption of improved technology [Ga04]. The objectives of the study were to quantify the production potential of peanut in Anhui, Hebei, Henan and Shandong provinces with special regard to water demand during the growing season. Water deficit is a major constrain in peanut production [Ri08], especially during the critical period of pod set which results in reduced pegging. An expert discussion at an international workshop about situation and prospects for groundnut production in China (1996) ranked drought stress on top of the major constraints for peanut production, ahead of acid soils, pests and diseases and cold temperature. For that purpose, the Decision Support System for Agrotechnology Transfer (DSSAT) [Jo03] crop growth model Vs. 4.5 was evaluated and validated using five years of yield data from the different provinces. Scenarios were driven using average weather data from 1976-2005 and eleven meteorological stations across the North China Plain.

2 Materials and methods

Within the DSSAT crop growth model, CROPGRO-Peanut is a generic grain legume model that computes crop growth processes including phenology, photosynthesis, plant nitrogen, carbon demand, and growth partitioning. In addition, the plant development and growth module is linked to soil-plant-atmosphere modules. Hence, the model has the potential for large area yield estimation by input of soil and daily weather data [Ga06]. For evaluation and validation of the CROPGRO-Peanut model, weather data from local weather stations of each province was taken [Bi08] [Ch07]. Physical properties of the provincial predominant soil texture classes [Xi86] silt (Anhui, Hebei, Henan) and sandy loam (Shandong) were derived from [Ch97], [Bö04], and [Bi08]. Average yield from Anhui, Hebei, Henan and Shandong provinces were taken using data from [Ch01]. A cross validation was done for Anhui for the years 2001/02/04/05, for Shandong for the years 2001/02/03/04, for Hebei for the years 2001/02/03/04/05 and for Henan for the years 2002/04/05 using the pre-evaluated DSSAT cultivar 'Chinese TMV2 TAM' (Nongshen type) for Anhui, Hebei and Henan and the 'Florigiant new' (Virginia type) for Shandong as initial point. According to the cross validation, the cultivars' coefficients were slightly modified for the four provinces. An average plant density of 40 plants m^{-1} within a hill planting system was used, taking the polythene mulching practice into account. As peanut is a leguminous plant, a balanced fertilization of 20 kg N ha^{-1} at sowing was applied for model evaluation. For each province, yield potential was simulated for average daily incoming solar radiation, minimum temperature, maximum temperature and rainfall using eleven meteorological weather stations' data. Subsequently, irrigated and rainfed scenarios within a sensitivity analysis were driven in order to detect whether long-term average rainfall could meet the water demand.

3 Results and discussion

The model showed a good fit between observed and simulated yield after the cross evaluation and validation procedure (Fig. 1). Mean observed yield of Anhui was 3625 kg ha^{-1}, mean simulated yield 3640 kg ha^{-1} with a RMSE of 300 (model error = 8.3 %). Mean observed yield for Hebei was 3028 kg ha^{-1}, mean simulated yield 3030 with a RMSE of 315 (model error = 10.4 %). For Henan, mean observed yield was 3410 kg ha^{-1} and mean simulated yield 3391 with a RMSE of 46 (model error = 1.4 %). Mean observed yield in Shandong was 3713 kg ha^{-1}, mean simulated yield 3718 kg ha^{-1} with a RMSE of 196 (model error = 5.3 %). Overall cross validation had a RMSE of 252 (model error = 7.37 %). Mean observed yield of all provinces was 3420 kg ha^{-1}, mean simulated yield 3422 kg ha^{-1}. For each province, three simulation scenarios were chosen: 1.) 20 kg N ha^{-1} at sowing with supplement irrigation; 2.) 20 kg N ha^{-1} at sowing, rainfed; 3.) neither nitrogen nor water stress. The results are shown in Table 1:

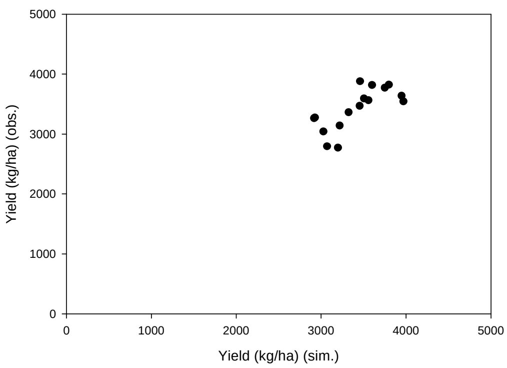

Figure 1: Mean observed peanut yield of Anhui, Hebei, Henan and Shandong provinces versus mean simulated yield after cross evaluation and validation of the CROPGRO-Peanut model.

Table 1: Simulated peanut yield of Anhui, Hebei, Henan and Shandong provinces using average weather data from 1976-2005 and three different scenarios.

	Anhui	**Hebei**	**Henan**	**Shandong**
Scenario	**Yield (kg ha^{-1})**	**Yield (kg ha^{-1})**	**Yield (kg ha^{-1})**	**Yield (kg ha^{-1})**
20 kg N ha^{-1}, irrigated	3848	3216	3877	4485
20 kg N ha^{-1}, rainfed	3848	3254	3914	2746
no N/water stress	3903	3244	3927	4482

As reported, peanut is very susceptible for water deficit. In the North China Plain, 50-75 % of the total rainfall occurs between July and September. In most years, the amount of rainfall is enough to satisfy the demand. Water shortage may occur at the beginning of the growing season of peanut as peanut is generally sown between mid of April and mid of May in these regions, and may last until the critical phase of pod setting around 50 days after sowing. The simulation showed that for Anhui and Henan, the long-term average rainfall met the demand of peanut. No supplement irrigation would be needed.

In contrast, the average rainfall in Hebei and especially in Shandong was not enough to satisfy the demand. Without irrigation, peanut yield decreased notable in Shandong. Shandong is the most important peanut region in China [Ch09] [Ga04] with the highest yield potential. The sandy soils predominant in Shandong were more likely to desiccate than the silty soils in the other provinces. [Ri08] reported from Argentina, that water stress promoted a significant decline up to 73 % in peanut seed yield because of reduced seed and pod numbers. Accordingly, a notable reduction in pod number for Shandong was simulated by the model. The CROPGRO-Peanut model was able to simulate and estimate large area yield for the four major peanut producing provinces in China. To study the potential yield of peanut with special regard to water demand, the approach was useful comparing possible lacks in demand with average rainfall. Further on, the model setting could be used for additional scenario and sensitivity analysis[1].

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