THE POTENTIAL OF APPLYING DECISION SUPPORT SYSTEMS TO IMPROVE AGROTECHNOLOGY TRANSFER IN THE RAINFED AREAS OF THE LOESS PLATEAU IN CHINA

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Abstract: Three soils in the Loess Plateau were selected to explore the potential of applying the decision support system for agrotechnology transfer (DSSAT) crop models in the areas and to test the CERES-Wheat model under DSSAT shell. The predicted maturity dates and grain yields were similar to the actual measured values. The manural loessial soil had the highest productivity. The loessial soil had the lowest productivity. Predicted yields for different terrains of the loessial soil showed that the soil in the plain lands and the table lands had a higher productivity than that of the slope lands and the terraces.

Keywords: crop modeling; decision support system; loess soils; rainfed agriculture

1 Introduction

The Loess Plateau is located in the northwest of China and covers about 530,000 km^2. The plateau is a major region for crop production in China. However, it is also famous for its wide distribution of loess that has resulted in serious soil and water erosion. The plateau has a warm-temperate climate and has extensive agricultural systems that consist of predominantly one crop per year. Most of the plateau belongs to the semiarid areas and receives between 250 and 500 mm of annual precipitation. Rainfall occurs mainly between June and September, accounting for 70% to 80% of the yearly total.

All areas in the plateau have deep yellowish soils that generally vary from 50 to 80 m in depth. The region has three major soils: manural loessial soil (silt loam), dark loessial soil (loam) and loessial soil (sandy loam). The soils are relatively uniform in texture, column-shaped in structure, fragile in strength, and consist of loamy blown deposits. All three soils are high in lime and potassium, low in organic matter, deficient in nitrogen and phosphorus, and have a relatively high water-holding capacity (up to 20%).

Most studies conducted in the plateau showed that the two main constraints for agricultural development are low soil fertility and lack of adequate soil water supply during the main growing season (Li & Xiao, 1992; Hu et. al., 1993). It therefore has become critical to use new advanced technologies to improve soil fertility and conserve soil water for crop production. However, it is difficult to conduct unified field experiments when soil types and soil fertility differ, rainfall varies, and with different terrains. It is also difficult for scientists and technicians to review their research achievements, to evaluate and disseminate new developed technologies to farmers and to provide recommendations to decision makers. The decision support system for agrotechnology transfer (DSSAT) software can be used to summarize and analyze experimental results and to transfer new technologies to farmer technicians, farmers and decision makers.

DSSAT version 3 (DSSAT v3) consists of a set of computer programs accessible under one shell. It is designed to enter, store, and manipulate weather, soil and crop data; run crop simulation models; and analyze crop model outputs (Hoogenboom et al., 1994). There are a number of crop models in DSSAT v3, and one of key aspects of DSSAT is that the crop models share identical input and output formats. The models are based on biophysical processes, using daily time steps for integration (Tsuji et al., 1994). To run DSSAT v3, a minimum data set is required with respect to weather, soil and experimental data.

The objective of this paper is to explore the potential of applying the DSSAT crop models and to use recent soil survey data to test the CERES-Wheat model in the rainfed areas of the Loess Plateau.

2 Materials and methods

Three locations of the Loess Plateau were selected for these simulations. They include Xian, Pingliang and Yanan. The WeatherMan program of DSSAT v3 was used to generate 30 years of daily weather data. The historical mean monthly weather data including mean daily maximum and minimum air temperature, mean total precipitation and mean total sunshine hours from 1951 to 1980 were used to define the climate input files for three locations of the Loess Plateau. The manural loessial soil is widely distributed in Weihe river plain where Xian is located, the dark loessial soil is distributed in northern of Weihe plain where Pingliang is located, and the loessial soil is widely distributed in northern of the the plateau and weather data were collected from Yanan for this soil. Recent soil survey data in the top 2 m (soil texture, soil available N, P and K, Total N, organic mater, pH, CEC, bulk density and carbonates content) were used to define the soil input files for the crop model. Winter wheat (*Triticum aestivum* L.) was selected as it is the dominate crop. For most areas of the plateau crop management was the same for each location, except planting dates. In order to meet the planting conditions for winter wheat, the planting date was set to a range of dates according to the actual planting date distribution for each location. The earliest sowing date was set to September 10, and the latest sowing date was set to October 20. To explore effects of different terrains on wheat production, four terrains were selected in the loessial soil in Yanan. They were plain lands, table lands, slope lands, and terraces. For this study, only soil conditions are different while weather conditions and crop management were the identical.

Two fertilizer treatments were applied: no nitrogen fertilizer and one nitrogen fertilizer application of urea at a rate of 125 N kg ha^{-1}, applied at planting. This rate corresponds to the standard fertilizer rates recommended by the extension services. The CERES-Wheat model was run for both fertilizer treatments at all three locations, using 30 years of generated weather data.

3 Potential of using DSSAT in the Loess Plateau

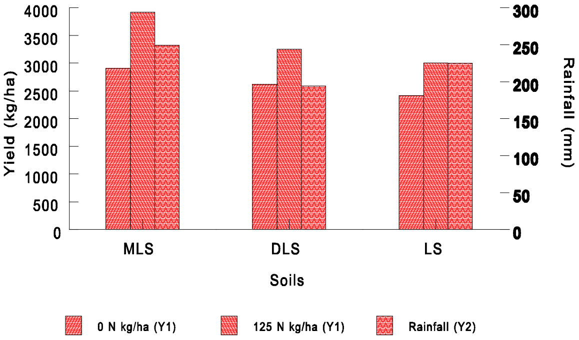
In the dryland area, the response to nitrogen fertilizer rates varied from year to year, much of this variation was due to differences in drought stress. To be able to apply the DSSAT crop models in the Loess Plateau, it is important to test the crop models for the local environmental conditions and management scenarios. The first step was to modify the soil file in the DSSAT models, including adjusting nitrogen fertilizer use efficiency for different drought stress conditions, and linking the interaction between soil fertility and soil water use efficiency. While in the semiarid area of the plateau, where timing and placement of fertilizer application may be critical as well, the simulation of root distribution enables the models to have sensitivity to fertilizer management. These are the advantages of using the DSSAT crop models to predict crop production in the whole region.

In the Loess Plateau, improving soil fertility is a key measure for increasing crop production. The main practice to improve soil fertility is to apply chemical fertilizers (Li & Xiao, 1992). Normally farmers can not afford the chemical fertilizer inputs recommended by extensionists. The farmers are resource poor and are not willing to take the risk of applying fertilizer under dry weather conditions. Therefore, during recent years it has become difficult for farmers to apply fertilizers at the recommended level at a large scale. The key for the region's development is an effective transfer of new technologies to match the farmers' resources of climate, soil, labor, and capital. The DSSAT crop simulation models integrate environmental conditions such as soil and weather and crop management scenarios. The crop models can predict the crop yields that farmers can expect given the limited resources, and they can also give recommendations to farmers to improve their management practices for crop production. This could provide potential for an effective agrotechnology transfer under different situations.

Soil water conservation is also an important measure to increase crop production due to the low and uneven distribution of precipitation. Most of the plateau has a lack of supplemental underground and surface water for irrigation and terrains vary in relative small areas. A fundamental measure to improve crop production is therefore to increase the storage of precipitation in the soil for later use. Loess soils can be big reservoirs and can store 550 to 600 mm of rainfall in the top 2 m of the soil profiles (Li, 1982). Farmers have accumulated a lot of experience with response to soil water conservation using traditional practices, such as soil compacting using machinery, mulching using both plastic film and crop residues, and application of different tillage methods. The DSSAT crop models incorporate a soil water balance that includes calculations of runoff, evaporation, drainage, and extraction of soil water. Water that is stored in soil prior to planting is also simulated in the DSSAT models. Applying DSSAT in the loess region can not only show the importance of rainfall during crop growing season but also show the importance of soil water harvesting practices on crop production during concentrated period of rainfall prior to planting.

4 Simulated results

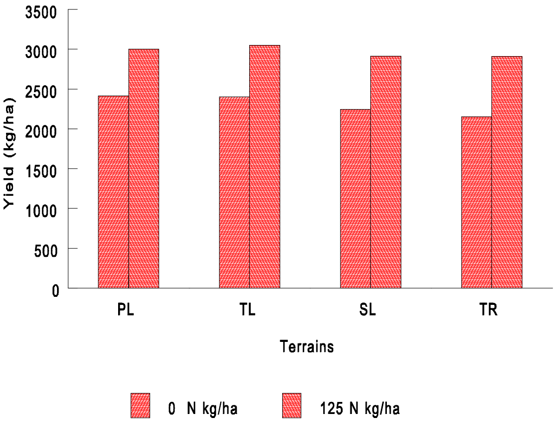
The predicted maturity dates were similar to the observed maturity dates for all three sites. The predicted harvest date for the manural loessial soil varied from June 1 to June 15. The actual harvest date ranged from June 2 to June 12. For the dark loessial soil and the loessial soil, the predicted harvest dates ranged from June 21 to July 5 and from June 17 to July 1, respectively.



The predicted grain yields for the three sites are shown in figure 1. The yields were similar to the actual yield levels. The manural loessial soil had the highest productivity among the three soils both with and without the nitrogen fertilizer application. This was due to the long cultivation history of the soil as well as the high soil fertility. The loessial soil had a lower productivity than the dark loessial, although total precipitation received by the dark loessial soil during growing season was lower than that of the loessial soil (Fig. 1). This is probably due to the higher soil fertility of the darkloessial soil compared to theloessial soil.

The results also showed that the year to year yield variation of the nitrogen fertilizer treatment was greater than the non-fertilizer treatment for all three locations. These variations were mainly caused by the yearly climate variabilities. For example, the yields in the manural loessial soil with and without nitrogen fertilizer were 5,503 and 3,272 kg ha^{-1}, respectively, when precipitation was 316 mm during wheat growing season. However when the seasonal rainfall was only 193 mm during a dry year, the yields for two treatments were 3,012 and 2,323 kg ha^{-1}, respectively. The difference in the two years was 2491 kg ha^{-1} with nitrogen fertilization, and was 949 kg ha^{-1} without nitrogen application. These differences also implied that nitrogen fertilizer use efficiency was low in dry years and high in the relatively wet years. Therefore, there might be a need to modify the nitrogen fertilizer use efficiency as function of drought stress in the CERES-Wheat model.

Four loessial soil terrains were selected in Yanan to better understand the effect of terrains on wheat production. For both treatments, the plain lands and the table lands had higher productivity than the slope lands and the terraces. The yield of the slope lands was slightly higher than the yield of the terraces (Fig. 2). These differences depended on the land distributions and cultivations. The plain lands are located in the river volleys, and the table lands are located in highland plains. Both of them had a long cultivation history and a higher soil fertility. The slope lands also had a long cultivation history, but soil erosion and water runoff was higher compared to the other terrains. Most terraces have been built during the last 30 years and are inconveniently for cultivation because they are spread out across hillside.



5 Discussion

The DSSAT crop models have been designed to accelerate the process of knowledge dissemination and to provide decision makers with alternative scenarios to evaluate the potential outcomes. The Loess Plateau has its own natural environment, such as rich in solar radiation and high in soil potassium which are advantages for crop production. However, they are deficient in soil nitrogen and phosphorus, and lack sufficient soil water supply. Both are the main constraints that limit the region's sustainable development. In order to run the DSSAT crop models in the area effectively, it was necessary to validate the models based on the natural conditions.

The predicted maturity dates and grain yields were similar to their actual records. The manural loessial soil had the highest productivity. The productivity of the loessial soil was the lowest. Soil fertility was a major factor of affecting crop production in the plateau. Soil in plain lands and table lands had higher productive than that in slope lands and terraces. The predicted grain yields varied from year to year in all three soils, and the variation was increased with nitrogen fertilizer application.

Through running the CERES-wheat model in the three sites of the Loess Plateau, we demonstrated that the DSSAT crop models can be used to estimate crop production for the entire region of this plateau and can be used to disseminate new technologies as well.

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