INTEGRATING REMOTELY SENSED LAI WITH EPIC MODEL BASED ON GLOBAL OPTIMIZATION ALGORITHM FOR REGIONAL CROP YIELD ASSESSMENT

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Abstract:

Timely and accurate information of crop growth situation and yield is very critical to issue of food security in a region or a country. So, in order to acquire the accurate crop yield information to make right decisions and win initiative in the international food market, the leaders of each country have always been thinking much of the crop growth monitoring and crop yield estimation in the main producing region of grain in their own country or in the world.

At present, the main models for crop yield estimation include climate model, remote sensing model and crop growth model. But each model has its own shortcomings. For example, climate model emphasizes particularly on empirical relationships and one established model only can be used in a designated region; remote sensing model can reflect the apparent information of crop growth and can provide a lot of spatial information but is strongly affected by its spatial and temporal resolution. The mechanism of crop growth model is good but it needs a lot of parameters to drive the model such as climate data, soil information, agricultural management information (including fertilizer application and crop planting date, etc) and crop variety information. Especially, some parameters such as agricultural management information are very critical to crop growth model but can’t be gotten easily at large scale. These situations have hindered the effective application of crop growth model in the crop growth monitoring and yield estimation at regional scale. So, these above kinds of model must be integrated so as to use their own advantages. In this paper, in order to take advantage of the remote sensing technology and crop growth model, we would assimilate remote sensing data such as leaf area index (LAI) into crop growth model to simulate the crop yield and some agricultural management information.

In this study, the crop growth model used was EPIC (Environmental Policy Integrated Climate)

model which was developed in America in 1984 and is suitable to most of all crop simulation. The optimization algorithm in this research was shuffled complex evolution (SCE-UA) method which was developed by Q. Y. Duan in 1992. Global optimization, efficient calculation, no need to calculate the derivative of objective function is the main character of SCE-UA optimization algorithm. At the same time, SCE-UA is not sensitive to parameter initialization value which avoids optimization process relying on the prior knowledge and derivative of objective function excessively. The flow chart of this research was as follows:

1) Union the basic regular network file (1km * 1km), the county administrative boundary and the soil coverage file (1:4,000,000) to generate the final elemental mapping unit (EMU).
2) Interpolate the climate station data of each day such as maximum temperature, minimum temperature, precipitation, total radiation, average wind speed and air humidity and use Neural Network method to calculate the LAI of each critical crop growth stage based on the VI (Vegetation Index) which were downloaded from NASA website
3) Retrieve the mean value of interpolated climate data and regional LAI for each EMU using zonal analysis method.
4) Prepare all soil data, field management data and other auxiliary data for regional EPIC model.
5) Set the initial value and the range for each assimilated parameters, then run the regional EPIC model. Sowing date, the total sum of irrigation, net N fertilization application amount, plant density, maximum potential leaf area index, the fraction of growing season when leaf area decline, two points on optimal leaf area development curve, leaf area index decline rate parameter were selected as assimilated parameters based on the expert knowledge, references and our model calibration.
6) Build the objective function based on the simulated LAI of each EMU and retrieve LAI based on VI of each EMU, if the objective function finds the global optimal point, then stop the program and go to step 7; else, go to step 5, recalculate the assimilated parameters' value.
7) Output the final assimilated parameters' value and final yield of each EMU.

Our study area is located in Hengshui City, Hebei Province, which is a part of Huanghuaihai Plain in North China. It includes 11 counties covering about 8815 km^2 extending northward from 37.09°N to 38.06°N and east-west between approximately 115.19°E and 116.53°E. Winter wheat-summer maize is the dominant double cropping system in the region. The summer maize of the year of 2004 was selected as

our research crop.

Finally, we got the simulated summer maize yield and the information of sowing date, the total sum of fertilization and plant density. Compared with the statistical crop yield data of the year of 2004 and field management information at county level, the mean relative of error of estimated yield was 4.37%, RMSE of estimated yield was 0.437t/ha. The maximum of relative error of estimated yield was 10.71% and minimum of relative error was -1.89%. The differences between the simulated sowing date and observed sowing date were 3 days. The simulated results of net N fertilization application amount and plant density were 187.74kg.ha^{-1}, 5.81×10^4 plants.ha^{-1}, respectively. The relative error of simulated results of net N fertilization application amount and plant density were -10.60% and -7.78%, respectively. We could see that the above simulated data were good. Also it was proved that EPIC model had been succeeded in coupling SCE-UA algorithm and the spatial LAI data derived from remote sensing image had been succeeded in assimilating into the crop growth model to simulate crop yield and other important crop growth and management information at regional level. In the near future, we would do more research in a larger region.

Key words: Crop growth model; EPIC; Data assimilation; Remote sensing; Global optimization algorithm; Yield estimation; LAI