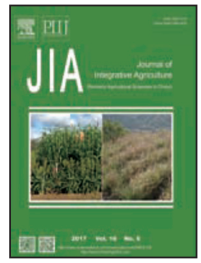
Journal of Integrative Agriculture 2017, 16(6): 1197–1210

Available online at www.sciencedirect.com

ScienceDirect



REVIEW

Modeling the biomass of energy crops: Descriptions, strengths and prospective

JIANG Rui[1, 2], WANG Tong-tong[1], SHAO Jin[3], GUO Sheng[1], ZHU Wei[1], YU Ya-jun[4], CHEN Shao-lin[2], HATANO Ryusuke[5]

[1] *Key Laboratory of Plant Nutrition and the Agri-environment in Northwest China, Ministry of Agriculture/College of Natural Resources and Environment, Northwest A&F University, Yangling 712100, P.R.China*
[2] *Biomass Energy Center for Arid and Semi-arid Lands, Northwest A&F University, Yangling 712100, P.R.China*
[3] *College of Water Resources and Architectural Engineering, Northwest A&F University, Yangling 712100, P.R.China*
[4] *College of Geography Sciences, Shanxi Normal University, Linfen 041000, P.R.China*
[5] *Graduate School of Agriculture, Hokkaido University, Sapporo 060-8589, Japan*

Abstract

The assessment of the biomass of energy crops has garnered widespread interest since renewable bioenergy may become a substantial proportion of the future energy supply, and modeling has been widely used for the simulation of energy crops yields. A literature survey revealed that 23 models have been developed or adapted for simulating the biomass of energy crops, including *Miscanthus*, switchgrass, maize, poplar, willow, sugarcane, and *Eucalyptus camaldulensis*. Three categories (radiation model, water-controlled crop model, and integrated model with biochemical and photosynthesis and respiration approaches) were addressed for the selected models according to different principles or approaches used to simulate biomass production processes. EPIC, ALMANAC, APSIM, ISAM, MISCANMOD, MISCANFOR, SILVA, DAYCENT, APEX and SWAT are radiation models based on a radiation use efficiency approach (RUE) with few empirical and statistical parameters. The AquaCrop model is a typical water-crop model that emphasizes crop water use, the expression of canopy cover, and the separation of evapotranspiration to soil evaporation and plant transpiration to drive crop growth. CANEGRO, 3PG, CropSyst and DSSAT are integrated models that use photosynthesis and respiration approaches. SECRETS, LPJmL, Agro-BGC, Agro-IBIS, and WIMOVAC/BioCro, DNDC, DRAINMOD-GRASS, and AgTEM are integrated models that use biochemical approaches. Integrated models are mainly mechanistic models or combined with functional models, which are dynamic with spatial and temporal patterns but with complex parameters and large amounts of input data. Energy crop models combined with process-based models, such as EPIC in SWAT and CANEGRO in DSSAT, provide good examples that consider the biophysical, socioeconomic, and environmental responses and address the sustainability and socioeconomic goals for energy crops. The use of models for energy crop productivity is increasing rapidly and encouraging; however, relevant databases, such as climate, land use/land cover, soil, topography, and management databases, are

Received 9 December, 2016 Accepted 21 March, 2017
JIANG Rui, Mobile: +86-15191864899, E-mail: jiangrui@nwsuaf.edu.cn; Correspondence WANG Tong-tong, Mobile: +86-18829841695, E-mail: tongtwang@163.com

© 2017, CAAS. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
doi: 10.1016/S2095-3119(16)61592-7

scarce. Model structure and design assumptions, as well as input parameters and observed data, remain a challenge for model development and validation. Thus, a comprehensive framework, which includes a high-quality field database and an uncertainty evaluation system, needs to be established for modeling the biomass of energy crops.

Keywords: biomass, energy crops, models, database, principles

1. Introduction

Renewable bioenergy may become a considerable proportion of our future energy demand due to the declining availability of fossil fuels, the growing population of the world and the environmental implications of greenhouse gas emissions. Energy crops, such as C_4 perennial grass (i.e., *Miscanthus* and switchgrass), rapeseed, poplar, and *Eucalyptus camaldulensis*, are all with high yield potential and efficient conversion of radiation to biomass; thus, they are considered the most important bioenergy feedstocks (Dalgaard *et al*. 2006; Mendu *et al*. 2012; Gelfand *et al*. 2013). A parameter that can play a key role in the cost assessments of bioenergy is the biomass productivity of energy crops. However, biomass productivity is often one of the most uncertain factors in studies on biomass energy systems because most energy crops are not commercially produced at a large scale in most countries and are mostly limited to experimental plots (Zegada-Lizarazu *et al*. 2010).

Currently, the biomass productivity of energy crops is estimated on the basis of field experiments and crop growth models. A disadvantage of using field experiments for estimating biomass is that they may not be representative due to the spatial heterogeneity of site conditions (Nair *et al*. 2012). Fortunately, field experiments provide plot information that improve our agronomic understanding of how climate, genetics, soils and crop management practices, such as irrigation or fertilizer application, influence potential biomass production, which is also necessary for developing and evaluating crop growth models. Crop growth models are useful to explain and predict crop yields or changes in the environment at the field to regional scale. The value of exploring agronomic situations without being tried experimentally (or hard to test by experiment) is greater when the model can simulate some crops arranged in a series and when as many environmental limiting factors and cropping techniques as possible are included (Cabelguenne *et al*. 1999).

Crop growth models simulate biomass yields based on three situations: (1) potential growth, (2) water-limited growth and (3) actual growth. Potential growth is obtained when the crop is supplied with enough water and nutrients and is not suffering from weeds, diseases and pests (Nair *et al*. 2012). It depends only on the current state of the crop, the current temperature and radiation conditions. Water-limited growth depends on a limitation in water availability, which is different from potential growth. Actual growth includes all limitations that occur in practice, such as the shortage of water and nutrients and suffering from weeds, diseases and pests (van den Broek *et al*. 2001).

Several crop growth models have been used to forecast biomass yields for herbaceous and woody energy crops at various scales. The energy crops simulated by these models are switchgrass, *Miscanthus*, sugarcane, maize, *Arundo donax*, hybrid poplar, and willow. The first to apply a crop model to the analysis of biomass yield for *Miscanthus*× *giganteus* in a field study (Beale and Long 1995) was derived from the radiation model (Monteith 1977). Then, the use of a radiation model for estimating the yield of *Miscanthus* was also conducted in Ireland (Clifton-Brown *et al*. 2000, 2001a, b, 2004). Later, the ISAM (Integrated Science Assessment Model) and MISCANMOD were developed to assess the production of *Miscanthus* and switchgrass under both restrictive and unrestrictive water resources based on the radiation model (Jain *et al*. 2000; Khanna *et al*. 2008). Since the initial adaptation of the radiation model for *Miscanthus* and switchgrass, there has been a sharp increase in the adaptation of other existing crop models and the development of some new models specific for energy crops, such as the ALMANAC (Agricultural Land Management Alternatives with Numerical Assessment Criteria) model (Kiniry *et al*. 1996), the DAYCENT model (Parton 1998; Del Grosso *et al*. 2009, 2011; Dwivedi *et al*. 2015), CropSyst (Stöckle *et al*. 2003; Tingem *et al*. 2009), and the APSIM (Agricultural Production Systems Simulator Model) (Keating *et al*. 2003; Subash *et al*. 2015).

There have many models that have been developed and adapted to simulate the biomass of energy crops. However, there are only a few studies that review and compare these models. There is a need to provide a comprehensive overview of these models and highlight the emerging application trends. Therefore, the objectives of this study are as follows: (1) summarize the categories of these models and describe the principles for each category; (2) provide an overview for each energy crop model and their application; and (3) describe key strengths and weaknesses of the energy crop models and list a summary of future research needs.

Download English Version:

https://daneshyari.com/en/article/8875955

Download Persian Version:

https://daneshyari.com/article/8875955

Daneshyari.com