15. Cropping System: Its Future Thrusts and Strategies

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Abstract:

The simulation of cultivation systems has made great progress in the last 30 to 40 years. From a young scientist with inadequate computing power, the field has evolved into a robust and increasingly accepted science supported by improved software, languages, development tools and computing capabilities. However, the basis continues to be scientific knowledge from plant physiology, soil science and agro climatology and related areas. Plant system simulators contain mathematical equations that describe basic flow and transformation processes of carbon, water and nitrogen balance and are integrated daily or hourly by the computer program to predict the timing of plant growth, nutrient uptake, and water consumption, predict final yield and other plant characteristics and - yields. Crop simulation models are valuable educational tools to teach students and scientists the importance of considering and integrating all the driving variables that influence crop growth and yield in each production situation. The first courses on modeling crops were primarily about teaching students how to use crop models. However, crop models are now increasingly being used in more general Bachelor/Master courses to teach students the integrative aspects of agriculture.

There are many problems with the farming system, especially related to soil quality. Therefore, there is a need for climate-smart agricultural practices such as conservation agriculture, perennial cultivation, organic farming, reduced tillage or rotational grazing and minimal/justified use of chemical fertilizers (responsible for nitrous oxide emissions), which not only reduces greenhouse gas emissions from agricultural land but also soil quality improved.

Keywords:

Cultivation system, Agro climatology, Plant system stimulator cropping model.

15.1 Introduction:

The simulation of cultivation systems has made great progress in the last 30 to 40 years. From a young scientist with inadequate computing power, the field has evolved into a robust and increasingly accepted science supported by improved software, languages, development tools and computing capabilities. However, the basis continues to be scientific knowledge from plant physiology, soil science and agro climatology and related areas.

Plant system simulators contain mathematical equations that describe basic flow and transformation processes of carbon, water and nitrogen balance and are integrated daily or hourly by the computer program to predict the timing of plant growth, nutrient uptake, and water consumption, predict final yield and other plant characteristics and - yields. The aim of this review article is to set out our vision for how simulation of crop systems can fulfill important future roles in agriculture and the environment and to suggest how research can be prioritized to better support these roles. The paper begins with a historical overview of the beginnings of cropping system models, then discusses five major roles and uses of cropping system simulation in agriculture and the environment, concludes with a challenge for possible linkage of cropping models with molecular biology genetics, and suggests the need for continuous improvement scientific knowledge about cultivation system models.

15.2 History:

The use of cultivation system models and simulations has its origins in plant physiology, soil physics and the soil-plant-water processes. Early models focused primarily on crop carbon (C) balance under optimal conditions, where only solar radiation and temperature were the driving variables. A major focus has been on simulating plant canopy photosynthesis using leaf-level parameters (DeWit, 1965; Duncan, 1971), along with predicting plant development from their growth stages and studying strategies to increase reproductive yield. These plant modeling patriarchs soon moved on to developing simple whole plant models. At the same time, early agricultural engineers and soil physicists developed soil-plant-water balance models that predicted daily crop evapotranspiration, crop water uptake, and water flow processes in soils (Whisler et al., 1986). See Whisler et al. (1986) for an overview and history of crop simulation models up to the mid-1980s, including typical processes considered, required data, model testing, and applications. The crop aspects of many previous soil-water balance models were often quite simple, estimating daily growth based on light capture and radiation utilization efficiency.

Soil water balance models vary from one-dimensional tipping bucket water balance (Ritchie, 1985, 1998) to more complex Darcy-controlled water flows with two-dimensional flow such as 2-DSOIL (Ahuja, Ma, and Timlin, 2006) and RZWQM (Ma et al., 2003). The next improvement in cropping system models came with simulating soil nitrogen (N) balance with a simple tip-tip Nitrate-N plug flow to simulate N leaching. However, success was limited until improvement occurred in two major components: first, the crop C balance routines required to accurately estimate crop N requirements, and second, accurate routines to estimate soil organic matter mineralization required to estimate the supply of mineral N in the soil more than the amount derived from the applied fertilizer N.

There are many published soil organic matter models (see, e.g., Smith et al., 1997, who compared nine different soil organic matter models). The most cited organic matter models are CENTURY (Parton, Stewart, and Cole, 1988) and ROTHC (Jenkinson and Rayner, 1977), and these models often serve as reference models for many studies. Each of these models has flaws, and there are many difficulties in correctly simulating soil organic matter dynamics, even after 20 to 30 years of progress, because soils are so variable, and soil organic matter is complex.

15.3 Plant System Simulators as Teaching Aids:

Crop simulation models are valuable educational tools to teach students and scientists the importance of considering and integrating all the driving variables that influence crop growth and yield in a given production situation. The first courses on modeling crops were primarily about teaching students how to use crop models. However, crop models are now increasingly being used in more general Bachelor/Master courses to teach students the integrative aspects of agriculture. Courses on plant modeling (on modelling) were first offered by the Dutch modeling group in 2003 (K. Boote was a participant). The next group to offer a plant modeling course was Jones and Boote in 1984 at the University of Florida. Around this time (1983-1984), the International Benchmark Sites Network for Agro technology Transfer (IBSNAT) group was formed, and these scientists developed the Decision Support System for Agro technology Transfer (DSSAT) models and began conducting plant modeling workshops (Tsuji, Hoogenboom and Thorton, 1999).

This DSSAT modeling group, largely composed of the same scientists, ran a plant modeling course for U.S. and international scientists every one to two years for the next 20 years. The DSSAT scientists now work under a new umbrella, the International Consortium for Agricultural Systems Applications (ICASA). The number of courses offered and the number of academics taking the courses has increased over time until, in 2008, the DSSAT course was offered to 55 people simultaneously. Most participants were PhD and MS scientists with backgrounds in agronomy, agricultural engineering, agricultural economics, entomology, pathology, and information systems. About a third of the participants were graduate students at the time of taking the course, meaning most participants were already working in academic, government, and industry positions. G. Hoogenboom estimates that a total of 500 people participated in the DSSAT course training and over 2,500 scientists received a copy of the software through the International Consortium for Agricultural Systems Applications (ICASA, http://www.ICASA.net). J. W. Jones and K. J. Boote have offered essentially the same course as a University of Florida course annually or semi-annually since 2000.

The plant modeling courses were very valuable in training individuals to use the DSSAT software, but more importantly in training the scientists to think about the function of the entire system, to learn more about the individual processes involved and how they are related with the crop and to find out how the system models synthesize and link all processes.

15.4 Impact on Soil Quality:

In recent decades, a significant decline in soil health has been observed worldwide due to inappropriate agricultural practices and land uses (Arshad and Martin, 2002). These include excessive and unbalanced applications of inorganic chemicals, improper tillage, nutrient depletion, and many other anthropogenic activities (Xiubin et al., 2002). These agricultural management processes are used to supplement or even replace biological functions that disrupt the natural balance of the ecosystem (Kibblewhite et al., 2008) and lead to soil quality degradation. It has now become clear that developing higher yielding varieties and crop diversity for greater food production cannot solve the problems of poor soil quality, so it has now become essential to develop landscape-based soil quality monitoring methods in all regions of the world (Smith et al., 1993).

A logical first step in developing soil quality is to identify the most limiting factors through appropriate assessment techniques. The concepts of soil quality and soil health are extremely controversial in the soil science community (Karlen et al., 2008). Both are often used interchangeably in literature, but they are two different concepts. Soil quality is related to soil function (Karlen et al., 2003; Letey et al., 2003), while soil health represents soil as a finite, non-renewable and dynamic living resource (Doran and Zeiss, 2000). Soil quality considers those properties of the soil that can be influenced by management practices and could improve or degrade soil health (Curell et al., 2012).

However, soil health is best preserved as a holistic term that describes the overall health of the soil system itself rather than its quality/condition for providing a service. In addition, soil health describes the biological integrity of the soil community, the balance between the organisms in the soil and between the soil organisms and their environment. In recent years, soil quality has become a major concern in developing countries where production intensification is widespread. This intensification raises concerns about the vulnerability of agroecosystem productive capacity (AES) caused by deterioration in soil fertility and soil water balance (Azam et al., 2009). Research on soil quality has become increasingly important in assessing limiting factors (Wilson and Maliszewska-Kordybach, 2000).

There are many definitions of soil quality in the literature (Brejda et al., 2000; Kleinhenz and Bierman 2001; Singer and Ewing, 2000), but each definition focuses on soil function. These include the ability of soil to (1) provide nutrients to plants, (2) create an optimal environment for plant growth, (3) promote and sustain crop production, (4) provide habitat for soil organisms, (5) to mitigate environmental pollution, (6) resist degradation, and (7) maintain or improve human and animal health (Wang and Gong, 1998). More specifically, soil quality can be defined as the ability of a particular soil type to function within natural or managed ecosystem boundaries, maintain plant and animal productivity, maintain, or improve water and air quality, and support human health and habitat (Karlen et al., 1997).

Agriculture is highly dependent on certain climatic conditions, and agricultural practices such as burning crop residues, puddling, intensive tillage, and fertilizer use also impact the climate by emitting greenhouse gases (GHGs). Total greenhouse gas emissions from agricultural sources amounted to approximately 980016 900 megatons of carbon dioxide equivalent in 2008 (Vermeulen et al., 2012). Small climate changes have potential impacts on AESs through changes in both temperature and humidity (Venkateswarlu and Shanker, 2009). A possible impact of climate change is lower or too high soil water content in critical phases of the growing season. These greenhouse gases affect soil physical, chemical and biological properties, which relate to functional soil processes and can be used to assess soil quality status (Allen et al., 2011). Therefore, there is a need for climate-smart agricultural practices such as conservation agriculture, perennial cultivation, organic farming, reduced tillage or rotational grazing and minimal/justified use of chemical fertilizers (which are responsible for nitrous oxide emissions), which not only reduce greenhouse gas emissions from agricultural land reduced, but also improves the soil quality.

15.5 Cultivation System Management to Relief Problems:

The negative impact of Green Revolution technologies has given impetus to the search for alternative crops and farming systems with new farming methods that are more environmentally friendly and use natural resources more efficiently. The experimental findings show that the emerging problems can be mitigated or minimized through effective resource management in an integrated manner (Gangwar et al. 2004).

Cropping system diversification and improved productivity and profitability/Cropping diversification in areas where continuous cropping is in place. Cereal-cereal systems are in trend and are considered as one of the effective options to overcome the second-generation problems and achieve a breakthrough in productivity and Profitability advocated. Crop diversification can simultaneously provide many agronomic and environmental benefits while maintaining or increasing production efficiency (Stockdale et al. 2001). Several options are available to diversify the rice-wheat system (Yadav et al. 1998, Sarkar and Gangwar 2000, Katyal et al. 2002, Gangwar and Ram 2003, DMR 2004).

Crops such as peanuts *(Arachis hypogea L.*), faba beans (*Vigna mungo (L.*), maize, fodder sorghum (*Sorghum bicolor (L.) Moencha*) or vegetables such as okra (*Abelmoschus esculentus (L.) Moench)* are grown in Punjab offer viable and worthwhile alternatives to nutrientand waterconsuming rice cultivation. While crops such as potatoes, Indian mustard (*Brassica juncea (I.) Czemj. and Cosson),* vegetable pea (*Pisum sativum L.),* grain pea and sunflower (*Helianthus annuus L.*) as substitute crops, regularly or intermittently, can replace wheat. In the rice-wheat system, it is also possible to grow an early potato crop, harvested for table purposes in the last week of December, followed by late wheat, planted in the first week of January, with a total grain yield of 5-10%. 6 tones and that of the tuber 17-25 tons (Singh 2001). Furthermore, it has been found that an additional yield of 2 tons of oilseeds is achieved when sunflowers are grown instead of late wheat in spring (Singh et al. 1997).

Other alternative spring crops include grain legumes (green gram) and vegetables (onion, tomato, muskmelon, and radish) (Khurana et al. 1985, Roy et al. 1999). Vegetables such as okra and forage crops such as cowpea (*Yigna unguiculata (L.) Walp.)* and sorghum can replace rice in the rainy season (Khurana 1992).

The rice-potato-sunflower system provides the highest wheat equivalent yield (22.6 tons/ha), net income (Rs 35,260/ha), land use efficiency (86-87%), production efficiency (71 kg/day) and benefit-cost ratio (2.26) (Jaiswal et al. 1994).

The other profitable sequence was rice-potato-wheat. It has also been reported that rice-potato-peanut is significantly better than the existing rice-wheat system in Punjab with a wheat equivalent yield of 10.0 tons per annum (Katyal et al. 2002). Likewise, wheat yield was higher in the potato intercropping (4.2 tons' ha) than in the rice-potato-wheat sequence (1.69 tons' ha), while potato yield remained unaffected (Singh and ekhbn 1985). The inclusion of grain legumes in grain-based cropping systems had significant positive effects on crop yields and fertilizer N conservation (Singh and Varma 1999). Rice chickpea (Cicer arietinum L.) and rice berseem *(Trifliumalexandrinum L.)* could also be a better alternative for the rice wheat system (Sharma 1996, Dwivedi and Singh 1995). For the new alluvial zone of West Bengal, the rice-potato-jute cropping rotation was reported to be the most productive with a rice grain equivalent yield of 16.94 tons per annum and a profitability of Rs 5,1,4,651 per annum. Rice wheat-peanut was equally good with the highest energy production (31.45 x 106,000 cal/year) and a system stability index of 0.9-1.0 (Katyal and Gangwar 2001). In this zone, the inclusion of legumes or green manures in the rice-wheat cropping system is more worthwhile than the rice-wheat cropping system (Mandal and Sinha 1993, Sinha et al. 1994). Mandal et al. (1994) reported that intercropping of wheat with pulses produced higher yields and economic benefits than cultivating wheat alone. The maximum wheat-equivalent yield could be achieved by including potatoes or vegetable peas between rice and wheat crops (Kharub et al. 2003). Similarly, the rice potato-peanut system in Kalyani was found to be the most productive, profitable, and efficient (Samui et al. 2004).

15.5.1 Cultivation Systems and Weed Control:

Incorporating certain crops into row and cover cropping systems significantly reduces some nuisance weeds, further reducing the need for herbicides in areas where these weeds have reached worrisome levels. For example, Johnson grass (*Sorghum halepanse (L.) Pers.)* becomes the predominant weed in continuous corn-based systems but can be controlled by rotation with cotton (Hosmani and Maiti 1993). Similarly, switching from the rice-wheat and rice-potato system to another system without rice in the rainy season tends to result in a significant reduction in Phalaris minor population in wheat (Bhan 1987). By introducing the sugarcane-wheat system instead of the rice-wheat system, the Phalaris minor infestation is reduced to an almost negligible level, which otherwise cannot be achieved even by herbicides (Bhan 1987, Prasad et al. 1997). Malik et al. (1998) proposed an integrated approach involving herbicide use in crop rotation, zero tillage and crop diversification for effective management of Phalaris minor in rice-wheat system. Among the different cropping sequences in Kanpur, Varshney (1993) observed the lowest biomass of nutgrass *(Cyperus rotundus L.)* in sesame wheat (63 gim) followed by sesame wheat-green gram (83 gim) as compared to 598 gimpigeon pea-wheat-green gram sequence. Also. Maximum weed density was observed in jute when wheat or maize were grown in rotation, but there was little increase in broadleaf weeds in jute when potatoes were included in the rotation (Biswas and Das 1993). In the maize-potato cropping system, the inclusion of pearl millet (for green fodder) or sesame (for green manure) in summer was also found to be beneficial in reducing nutgrass in the subsequent crop of maize and potatoes (Tiwari and Singh 1991).

Cultivation of green manure during the dry season helped to reduce the weed problem in the subsequent rice crop in the paddy-rice system in Tamil Nadu (Gnanavel and Kathiresan 2002). They also found that incorporation of press mud at 10 tons/ha along with Azolla inoculation at 1.0 ton/ha was comparable to manual weed control twice in terms of weed control and crop yield.

15.6 Future Thrusts and Strategies:

The concept of complementary intensive intercropping systems that seek to grow morphologically and physiologically different crops in one agricultural year within the framework of sequential intercropping systems that exhibit complementarity among each other and successive associations (Gangwar 1983). This concept is relevant as water availability declines and deserves further consideration. Quantifying the impact of diversification options on productivity, stability, profitability, soil health, water, and nutrient use productivity, etc.

The diversification needs of the system are highly location specific and depend on available resources and other predictors. Therefore, location-specific strategies must be developed to achieve advantageous diversification benefits. A fixed system is not expected to last in the coming years. Therefore, diverse systems that are dynamic in nature and able to absorb change may be desirable. Efforts must be made to develop sustainable models using computer software to keep pace with changes in existing systems. Given current trends and future concerns, “organic farming systems” are likely to dominate our future research agenda. Therefore, the role of legumes and green manures both in association and in crop rotation and utilization of crop residues with minimal use of chemicals deserves due attention to diversify the existing agricultural systems and harvest high-quality products. The systems-based integrated resource management approach must be aimed at long-term sustainability. Develop a precise input management approach for potential cropping systems to optimize resource utilization and increase efficiency. Special efforts must be made in system-based technologies to conserve resources. For real success of cropping systems research, appropriate guidelines for multidisciplinary research must be developed through inter-institutional or inter-organizational collaborative programs. Development of appropriate decision support systems for diversification options and resource utilization to optimize under variable scenarios.

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