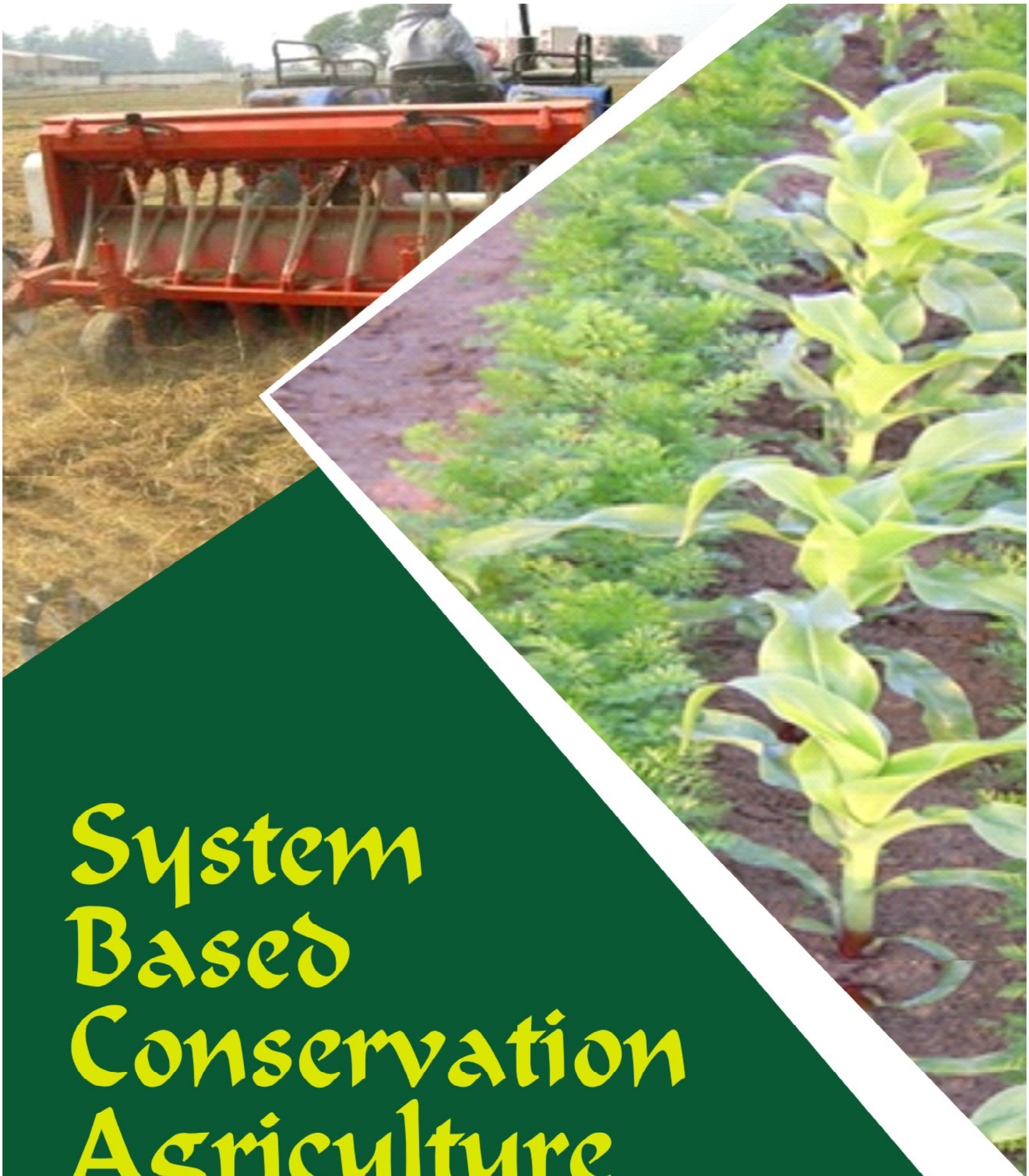

System Based Conservation Agriculture

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Decision Support System for Conservation Agriculture

M. Shamim, V.P. Chaudhary and N.K. Jat

Conservation agriculture (CA) represents a series of resource-conserving agricultural practices. Reduced or no tillage combined with crop residue and crop rotation are the principal components of conservation agriculture. In addition to these land configuration planting techniques e.g. permanent raised-bed systems are often applied in CA. All these various components add complexity to the cropping system not only challenges the applicability of crop-soil simulation model, but, also the effects of conventional soil tillage, such as the temporal decrease in soil bulk density and increase in water infiltration capacity as well as mixing of soil layers, i.e. of texture, organic matter and nutrients, are often not accounted for in crop-soil simulation models or are represented in a limited way. In classical model applications, this lack may be of little relevance. However, when models are used to explore the crucial differences between CA and conventional agriculture, changes in and effects on soil properties due to one or the other practice becomes highly relevant (Sommer *et al*., 2004).With three major advantages such as enhanced productivity, richer resources and highly climate resilient agricultural practices, adoption of conservation agriculture (CA) is increasingly being promoted as a way of climate smart agricultural practices towards increasing climate variability. To understand complex interactions among the biophysical processes, computer simulations have become a useful part of mathematical modeling of many natural systems. Crop simulation modeling started in early 1960s when early simple crop models were developed for estimation of transpiration and photosynthesis. The first step towards crop modeling was the development of simple models to estimate light interception and photosynthesis. These simple models were used to quantify the light profile in a canopy and to assess the sensitivity of crop photosynthetic rates. In recent decades, many cropping systems models have been evolved in response to answer not only nutrient and water deficiencies, but also pest and disease damage and processes affecting soil nutrient dynamics including issues on sustainable production, climate change, and environmental impacts. Among many crop simulation models, DSSAT (Decision Support System for Agrotechnology Transfer) is a comprehensive decision support system which, includes several routines to account for the impact of tillage and surface residue retention. Sommer *et al.* (2004) applied DSSAT and found that in the presence of a surface residue layer the classical soil conservation service (SCS) curve number approach fails to describe surface runoff adequately, because the residue layer increases surface roughness and retains water, which is not accounted for in the SCS approach. Also, in the presence of a residue layer soil evaporation is lower leading to comparably higher top soil moisture content and consequently to a higher runoff according to the SCS curves number method. The one-dimensional cascade approach used by the model to simulate soil water infiltration and drainage does not adequately capture the soil water redistribution in raised-bed cropping systems. Modifications are needed to account for these two processes.

In low input systems, where most nutrient becomes available from soil organic matter (SOM) and residue turnover, the applicability of the DSSAT is limited because it recognizes only one type of SOM (i.e. humus) and recently added, but not yet humified, residue and it does not recognize a residue layer on top of the soil. Newly formed is given a fixed C/N ratio of 10; only one litter pool is recognized for N although three are recognized for C. A SOM-residue module from the CENTURY model was incorporated in the DSSAT crop simulation model and a residue layer was added on top of the soil. This CENTURY-based module was added to facilitate simulation of soil organic sequestration potential for different crop rotations over long time periods after initializing soil C and other variables only once at the start of the simulation. The CENTURY model is more appropriate for use in low input agricultural systems, for example those that use green manure where the surface layer is crucial. The main differences between the CENTURY-based module and the CERES-based soil N module are: the CENTURY-based module divides the SOM in more fractions, each of which has a variable C: N ratio and can mineralize or immobilize nutrients, it has a residue layer on top of the soil, and the decomposition rate is texture dependent. The CENTURY-based module distinguishes three types of SOM: (1) easily decomposable (microbial) SOM1, (2) recalcitrant SOM2, which contains lignin and cell walls, and (3) an almost inert - SOM3. At initialization of the simulation, the fractional ratio of these three pools is set, with SOM1 of only about 2% of total SOM, while SOM2 and SOM3 vary with the management history of the soil (grassland or cultivated) and the degree of depletion. The improved SOM module also allows one to perform more realistic simulations on carbon sequestration, *i.e.* the build-up of soil organic C under different management systems. Evaluation of the model showed an excellent fit between simulated and measured values for SOM-C under bared field. By incorporating the CENTURY

SOM-residue module, DSSAT crop simulation models have become more suitable for simulating low-input systems and conducting long-term sustainability analysis (Jones *et al*., 2010).

Conservation agriculture (CA) is increasingly promoted as one way of adapting production systems under changing climate, especially for areas such as southern Africa where rainfall is projected to decrease.The DSSAT model was calibrated using field data and validated against independent data sets of yield to evaluate the ability of DSSAT to predict continuous maize (*Zea mays* L.) yield for conventional tillage (CT) and CA systems as well as maize yield for a CA maize–cowpea (*Vigna unguiculata*) rotation on an Oxicrhodustalf under southern African climatic conditions. Simulation showed that DSSAT could be used for decision-making to choose specific CA practices especially for no-till and crop residue retention. Long term simulations showed that maize–cowpea rotation gave 451 kg/ha and 1.62 kg/mm more maize grain yield and rain water productivity, respectively compared with CT. On the other hand, CT (3131–5023 kg/ha) showed larger variation in yield than both CA systems (3863 kg/ha and 4905 kg/ha). CT and CA systems gave 50% and 10% cumulative probability of obtaining yield below the minimum acceptable limit of 4000 kg/ha, respectively suggesting that CA has lower probability of low yield than CT, thus could be preferred by risk-averse farmers in uncertain climatic conditions (Ngwira *et al*., 2014).

1. ROLE OF CROP MODELING UNDER CLIMATE CHANGE SCENARIO

In recent years there has been a growing concern that changes in climate will lead to significant damage to both market and non-market sectors. The climate change will have a negative effect in many countries. But, farmer's adaptation to climate change-through changes in farming practices, cropping patterns, and use of new technologies will help to ease the impact. The variability of our climate and especially the associated weather extremes is currently one of the concerns of the scientific as well as general community. The application of crop models to study the potential impact of climate change and climate variability provides a direct link between models, agro-meteorology and the concerns of the society. Tables 1 to 3 present the results of sensitivity analysis for different climate change scenarios for rice cultivars under middle Gujarat Agro-climatic region.

2. EFFECTS OF MAXIMUM AIR TEMPERATURE

The effects of altered maximum air temperature (± 1 to ± 3°C) on simulated grain yield of various cultivars of rice under optimal date of transplanting and the comparison of this simulated grain yield with base yield and its per cent change from base yield are presented in Table 1.

Table 1: Sensitivity of CERES-Rice model to maximum air temperature (°C) for four different cultivars of rice

Parameters	*Cultivars*							
Base yield	*Pankhali 3793 kg/ha*		*Narmada 4243 kg/ha*		*Gr-104 4887 kg/ha*		*Pusa-Basmati-1 4177 kg/ha*	
Max. air temperature (°C)	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*
1	3487	-8.1	3962	-6.6	4593	-6.0	4134	-1.0
2	3432	-9.5	3910	-7.8	3914	-19.9	3801	-9.0
3	3339	-10.4	3870	-8.8	3856	-21.1	3686	-11.8
-1	3994	5.3	4380	3.2	5150	5.4	4580	9.6
-2	4287	13.0	4722	11.3	5689	16.4	4764	14.1
-3	4501	18.7	5050	19.0	5457	11.7	5057	21.1

Sensitivity of CERES-Rice model simulated grain yield to incremental units of maximum air temperature showed a gradual decrease in yield while the down scaled maximum temperature increased the yield in all four genotypes of rice. Maximum reduction in yield due to increment of same unit of maximum temperature was recorded in GR-104 genotype whereas cv. Pankhali recorded least reduction for corresponding temperature level. The highest positive percentage change in yield over base yield due to reduction of maximum temperature was recorded in Pusa Basmati-1 and least by the genotype GR-104. Such behavior of the model was mainly due to reduction in duration of anthesis and grain filling with rise in ambient temperature and *vice versa.*

3. EFFECTS OF MINIMUM AIR TEMPERATURE

The result of simulated yield when examined in relation to minimum temperature indicated decrease in yields with increase in temperature above that corresponding to potential conditions in all four genotypes of rice. But, the magnitude of change from base yields in terms of percentage was almost double that corresponding to the preceding level in all the increased level of maximum temperature in the case of Pankhali and Pusa Basmati-1 cultivars (Table 2).

This type of behavior shown by the crops might be due to dual effects of higher rate of respiration during night time resulted in to comparatively higher loss of photosynthates than that was occurred during day time due to increased maximum temperature and differential reduction in crop duration of different cultivars of rice. The reduction was however, less for the heat tolerant cultivar (Pankhali). Paradoxically, the low minimum temperature increased the yield in the all four genotypes of rice, but not in the same magnitude as that of reduction in yield with increase in minimum temperature and decrease in maximum temperature. All the four genotypes behaved differently in relation to change in minimum air temperature as the simulated yield did not increased linearly when minimum temperature was decreased up to 5°C in the case of Narmada and GR-104 genotypes. This result described the tolerant power of various genotypes of rice in relation to minimum temperature where, growth rate affected differently in different cultivars.

4. EFFECT OF ELEVATED CARBON DIOXIDE

The simulated grain yields increased under elevated level (410 ppm concentration over the base value 380 ppm) of CO_2 by 21.0%, 23%, 27.9% and 25.6%(Table3) in cv. Pankhali, Narmada, GR-104 and Pusa Basmati-1, respectively when compared with base yield. This clearly showed that elevated concentration of CO_2 had a significant and positive impact on the grain yield of various genotypes of rice, but GR-104 could be performed better under elevated concentration of rice than that of other genotypes.

Table 2. Sensitivity of CERES-Rice model to minimum air temperature (°C) for four different cultivars of rice

Parameters	*Cultivars*							
Base yield	*Pankhali 3793 kg/ha*		*Narmada 4243 kg/ha*		*Gr-104 4887 kg/ha^{-1}*		*Pusa-Basmati-1 4177 kg/ha*	
Max. air temperature (°C)	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*
1	3468	-8.6	3936	-7.2	4625	-5.4	3974	-4.9
2	3220	-15.1	3711	-12.5	3738	-23.5	3780	-9.5
3	3118	-17.8	3500	-17.5	3475	-28.9	3488	-16.5
-1	3964	4.5	4383	3.3	5166	5.7	4477	7.2
-2	4215	11.1	4683	10.4	5312	8.7	4686	12.2
-3	4498	18.6	5053	19.1	5504	12.6	4832	15.7

Table 3. Sensitivity of CERES-Rice model to elevated CO_2 concentration for various cultivars of rice

Genotypes	*Base yield(kg/ha)*	*Elevated CO_2 concentration (410 ppm)*	
		Simulated grain yield (kg/ha)	*% Change from base yield*
Pankhali	3793	4589	21.0
Narmada	4243	5241	23.5
Gr-104	4887	6250	27.9
Pusa Basmati-1	4177	5247	25.6

5. EFFECTS OF PLANTING METHODS

The change in planting method (Direct sowing) and their impacts on grain yields of various cultivars of rice as simulated by the model in comparison with base yield are presented in Figure 1. The yield reductions ranged between 12.4 (GR-104) to 14.4 (Pusa Basmati) percentage change from base yield. This indicated that the model functioned extremely well in detecting the effect of planting methods on simulated yield of rice.

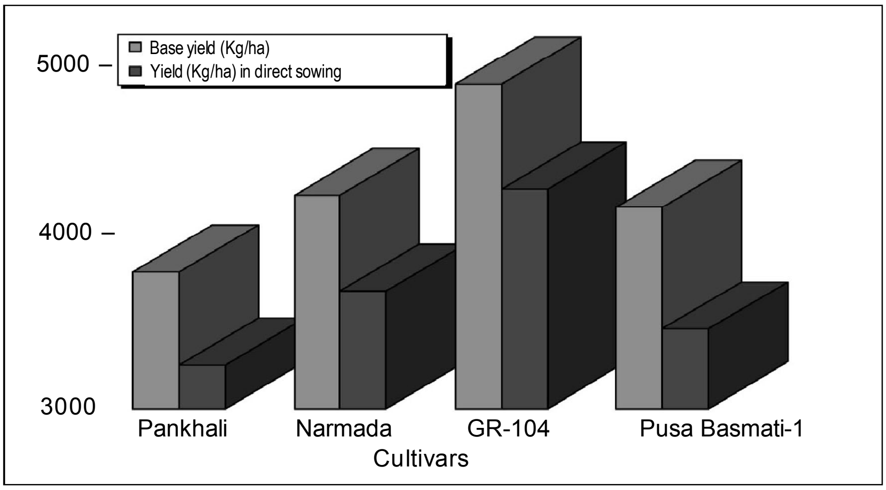

Fig. 1. Effects of direct sowing on grain yield of various genotypes of rice as compared with base yield

6. EFFECT OF PLANT POPULATION

Large yield reductions were observed on decreasing plant population up to 25 plants/m^2 in all cultivars, but Pusa Basmati-1 recorded highest (Table 3). However, model did not show any noticeable percentage change when compared with the base yield in relation to increasing the plant population from 75 to 200 per sq. meter. This showed the insensitivity of the model to varying plant population level.

Table 3. Sensitivity of CERES-Rice model to plant population (plant/m^2) for four different cultivars of rice

Parameters	*Cultivars*							
Base yield	*Pankhali 3793 kg/ha*		*Narmada 4243 kg/ha*		*Gr-104 4887 kg/ha*		*Pusa-Basmati-1 4177 kg/ha*	
Max. air temperature (°C)	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*	*Simulated grain yield (kg/ha)*	*% Change from base yield*
25	3125	-17.6	3475	-18.1	3847	-21.3	3269	-21.7
75	3802	0.2	4340	2.3	5092	4.2	4387	5.0
100	3862	1.8	4376	3.1	5125	4.9	4495	7.6
125	3919	3.3	4455	5.0	5151	5.4	4457	6.7
150	3862	1.8	4325	1.9	5212	6.7	4471	7.0
175	3902	2.9	4382	3.3	5291	8.3	4485	7.4
200	3942	3.9	4408	3.9	5321	8.9	4495	7.6

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The present publication deals with the scope and significance of refinement, adoption and dissemination of conservation agriculture (CA) in Indian *vis-à-vis* global context. Through this book, an attempt has been made to help readers to gain a precise understanding of the role of mechanization and the necessity for suitable modifications in the existing machinery for efficient residue recycling, crop establishment, optimized nutrient and water use, and weed management. Highlighting the collective work of various CA researchers, this reference book helps to understand the aspects like dynamics of macro and micro-nutrients along with the desired management alterations as per the CA principles. For the wider adoption of CA, location-specific crop diversification suited for different soil types has also been discussed in the book. The approaches like integrated farming system and organic farming in conjunction with CA principles for enhanced resource recycling, sustained livelihood in long-term perspective has been documented in the book. The impact of CA on soil quality, technologies designed for adaptation/mitigation for climate vulnerability, economics and system sustainability has been the focal point in the present book.

. . . This book is a perfect compilation of consorted efforts of various researches done in the direction of development, standardization and dissemination of the refined CA technologies. The emerging concerns of environmental unsustainability raised in the book necessitates the development of a policy framework promoting CA . . . I strongly believe that the book would be of great value to various stakeholders in addressing the goals of achieving sustainable agricultural systems through conservation agriculture . . .

– Dr Arvind Kumar
Vice-Chancellor
Rani Laxmi Bai Central Agricultural University, Jhansi

Readership: Researchers working on conservation agronomy, soil science, soil physics, environmental sciences, farm machinery and power, agricultural economics and extension. Undergraduate, post graduate students of different natural resource management disciplines in SAUs, all the stake holders including policy makers, state agriculture development departments involved in agricultural production in general and conservation agriculture in particular.

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