Systems modeling and farmers' participatory evaluation of cropping options to diversify peanut systems in Anantapur region, India. I: APSIM simulations to analyze constraints and opportunities

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Abstract

Peanut monocropping is the predominant rainfed system in semi-arid Anantapur region (Andhra Pradesh), India, where low rainfall and lighter alfisols support shorter length of crop growing season (105-135 days). To investigate how to minimize frequently occurring crop failures, we analyzed constraints and opportunities existing with peanut production systems following a systems simulation approach using APSIM. The three peanut systems were simulated using historical weather data at Anantapur (1962 to 1999) and included sole peanut, peanut/medium duration (MD) pigeonpea intercrop and peanut/short duration (SD) pigeonpea intercrop. Our analyses indicated peanut/SD pigeonpea intercrop system would minimize crop failure and record higher productivity by escaping water stress conditions in 7 of 31 crop seasons, when sole peanut or peanut/MD pigeonpea intercrop systems failed. Simulated SD pigeonpea yields were higher than MD pigeonpea yields in 19 crop seasons and showed a potential for >1.5 t ha^{-1} yields with peanut/ SD pigeonpea system in most of the good rainfall seasons. To further evaluate cropping systems options identified by systems simulation approach, verification demonstrations on peanut/ short duration pigeonpea intercrop system were planned with farmers' participation during 2000-2002 crop seasons.

Media summary

Peanut systems in semi-arid Anantapur region, India were analyzed using a systems modeling tool, APSIM to identify suitable cropping options for minimizing the risk of crop failures, and to improve system productivity in water scarce environment.

Key words

Peanut, pigeonpea, APSIM, simulated options, intercrop systems, climatic risks

Introduction

Peanut (*Arachis hypogea L.)* monocropping is a predominant rainfed system in Anantapur, parts of Kurnool and Cuddapah districts of Andhra Pradesh, and Kolar and Chitradurga districts of Karnataka in southern India. Peanut is grown on lighter Alfisols with low water-holding capacities (45 to 90 mm of plant available soil water) in Anantapur region. Mean rainfall during the crop season is low (460 mm) and erratic, results in droughts and shorter length of growing season (LGS); that varies between 105-135 days. Crop failures are common (in two out of five years) in this region, either due to frequently occurring mid-season droughts or insect and disease epidemics due to monocropping, like peanut stem necrosis that devastated the crop during crop season 2000(Picture 1). To minimize these risks, farmers prefer a peanut intercrop system without considerable yield reduction of peanut, and pigeonpea (*Cajanus cajan (L.) Millsp.)* intercrop that matures in 125-135 days to escape terminal stress, a setback that often affects MD pigeonpea as intercrop that matures in 150days or longer. Of late, a small percentage of farmers prefer to grow peanut/MD pigeonpea intercrop system at wider row ratios (Picture 2) (11:1 to 39:1) (Rego et al., 2001), instead of the recommended row ratio of 7:1 intercrop system.

Objectives

I. Application of systems modeling to identify suitable cropping options in peanut systems for minimizing the risk of total crop failure.

II. Capacity building of NARS collaborators in systems modeling through training in APSIM

Picture 1. Farmers uprooting disease affected sole peanut in mid-season 2000

Picture 2. Peanut and MD pigeonpea intercrop at wider row ratios in farmer's field

Methods

Inter-annual variability of LGS and peanut yields in Anantapur region

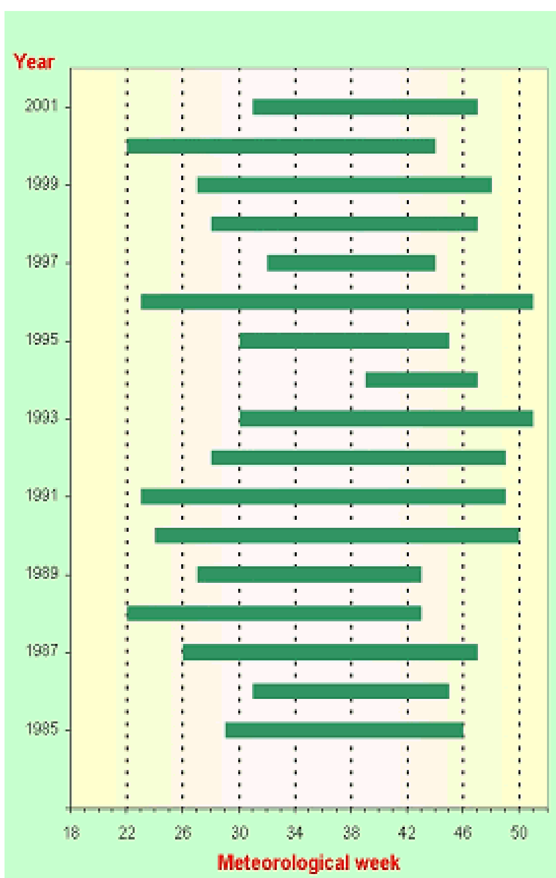

Figure 1. Variability of length of growing season in Anantapur region

We collected weather and soil data of Anantapur to determine the possible length of crop growing season on 50 cm alfisol profile from 1965 to 2001 (fig 1) using Thornthwaite and Mather (1955) water balance equation. District average peanut yields for a longer period, 1962 to 2001 (fig 2), were also collected to analyze peanut productivity in Anantapur. Average yield of peanut is low at 0.75 t ha^{-1}, with a standard deviation of 0.533 (t ha^{-1}). Inter-annual yield variability of peanut is very high (CV of 71%), mainly due to unreliable amount and distribution of seasonal rainfall, leading to variability in LGS (63-161 days) coupled with intermittent dry spells during growing season.

Model simulated scenario analysis to assess peanut systems

We performed long-term simulation for three peanut systems namely sole peanut, peanut/ SD pigeonpea, and peanut/MD pigeonpea intercrop systems with Agricultural Production Systems sIMulator (APSIM) (McCown et al., 1996) using weather data of Anantapur (1962-1999). Soil parameters for three soil profiles were obtained from different sources including Agricultural Research Station (ARS), Anantapur. Three different soil profiles of 30, 60, 90 cm depths having 47, 81 and 95 mm plant available water holding capacities respectively were set up for these simulations. Peanut cultivar (TMV 2), pigeonpea cultivars, ICP-88034 and LRG-30 were parameterized using data from ARS experiments (personal communication from Dr. Balaguravaiah).

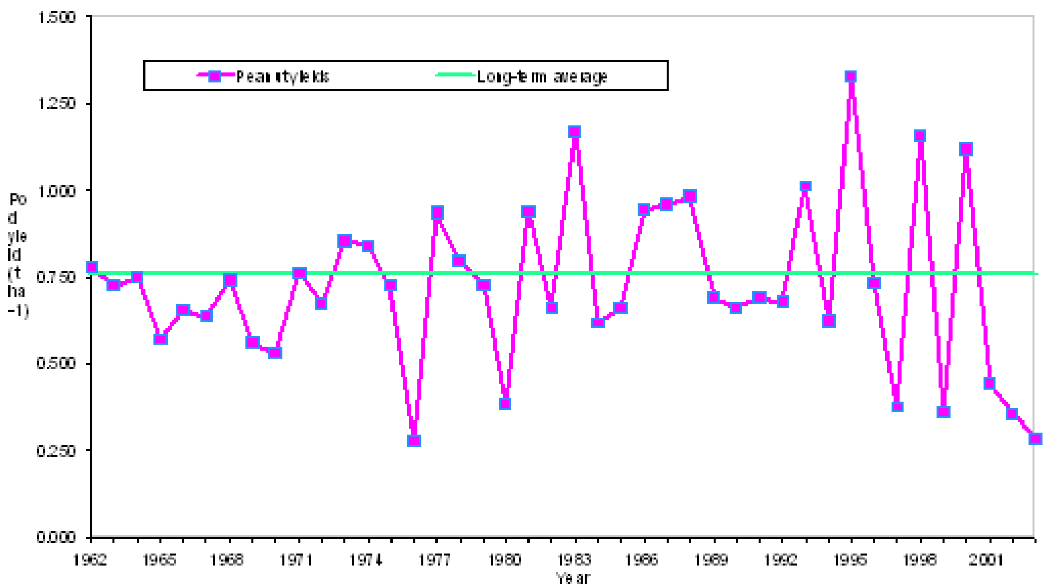

Figure 2. Inter-annual yield variability of peanut in Anantapur district during crop seasons 1962-2003.

These cultivars were used in simulations as component crops of peanut systems. Sowing event was logically derived within a sowing window between June 10 and August 30, when the soil profile had extractable soil water greater than 25 mm or the rainfall received within previous three days was greater than 30 mm. Sole peanut crop scenarios were simulated with 6 rates of peanut population (16, 20, 25, 30, 33 and 40 plants m^{-2}) at 30 cm row spacing. The recommended population is 33.3 plants m^{-2}. Scenarios were simulated with 6 rate of peanut /SD pigeonpea intercrop populations (16/8, 20/10, 25/12, 30/12, 33/16 and 40/16 plants m^{-2}) as well as peanut/MD pigeonpea (16/6, 20/6, 25/6, 30/6, 33/6 and 40/6 plants m^{-2}) populations at a row spacing of 30 cm for peanut and 90, 120, 150, 200 cm row spacing for pigeonpea in the intercrop systems. APSIM pigeonpea module (Robertson et al., 2001; Carberry et al., 2001) has a restriction on row spacing above 2000 mm for the intercropping, hence we could not simulate recommended row spacing of 2400 mm that configure at 7:1 row ratio of peanut/MD pigeonpea system. All simulations were set to report peanut and pigeonpea crop growth and yield attributes as well as variables such as soil water supply, crop demand and fraction of light intercepted by each crop component crop for identification of optimum population and row configuration for three peanut systems.

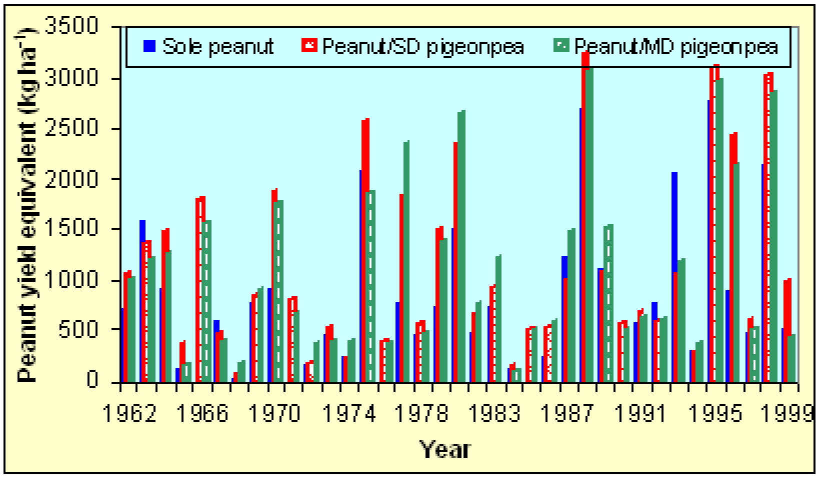

Figure 4. Simulated systems productivity of sole peanut and peanut/pigeonpea intercrop systems as peanut yield equivalent

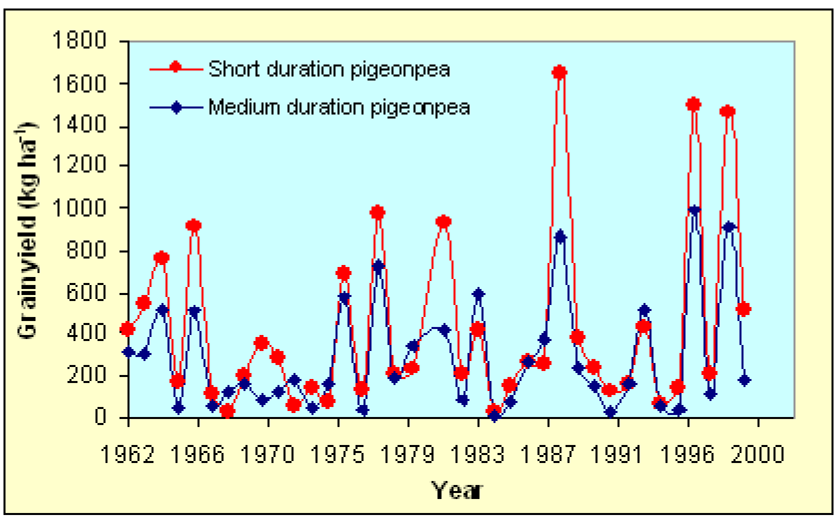

Figure 5. Pigeonpea yield scenario of sole and intercrop peanut systems on 30 cm soil depth alfisols during crop seasons 1962-99

Results of APSIM simulation studies

Simulated scenario analyses indicated peanut population of 250,000 plants ha^{-1} with an additive population of 120,000 plants ha^{-1} of SD pigeonpea in the intercrop system to be optimum for low and varying natural resources in this region, as against the recommended peanut population of 33.3 plants m^{-2}, for high input cultivation. Yogeswara Rao et al. (1992) concluded from a field study in Anantapur that a peanut population of 167, 000 plants ha^{-1} at harvest, could be sufficient to obtain potential yield in good rainfall years, but this was limited to a two year study. Although we had performed simulations and analyses of the results for three soil depths, we are presenting simulated data for 30 cm soil profile only as these dominate the production system in the district. Simulated productivity of the different peanut systems followed the same trend with 60 and 90 cm soil profiles but the productivity is higher with increased availability of water in soils, however limited by rainfall.

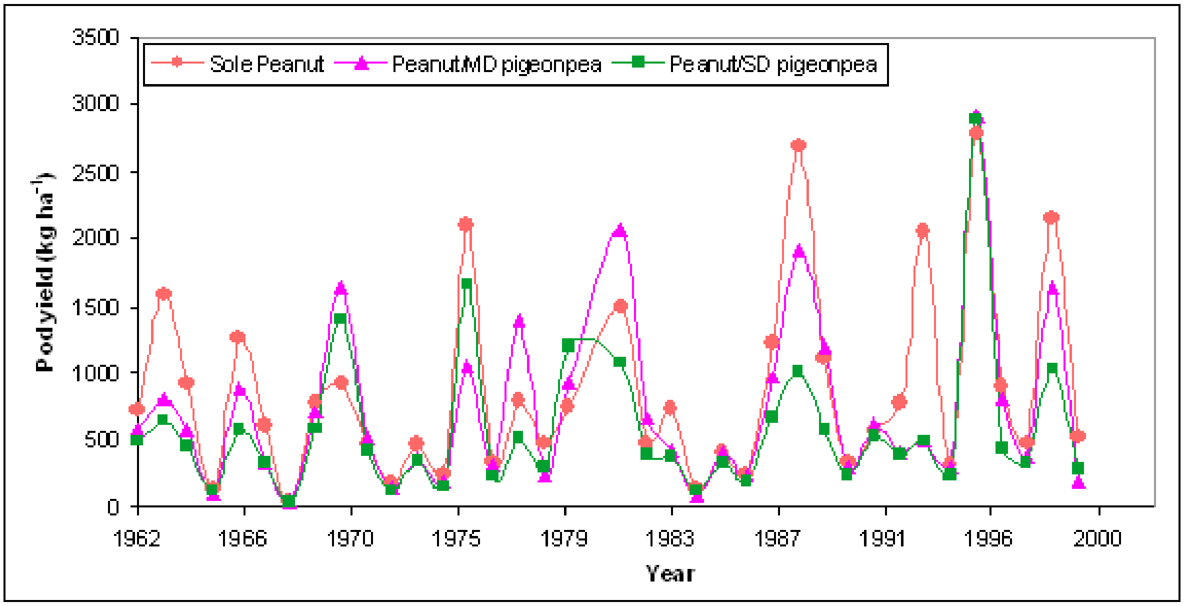

Figure 3. Peanut yield scenario of sole and intercrop peanut systems on 30 cm soil depth alfisols during crop seasons 1962-1999.

Simulated sole peanut yields were higher in most years (fig 3.) than either peanut/MD pigeonpea or peanut /SD pigeonpea, in the absence of pigeonpea competition. However, intercropping of peanut at row spacing of 30 cm / SD pigeonpea at 120 cm (3:1 row ratio) was found to have a LER of 1.57 compared to sole peanut similar to observations in field experiments (Rao and Mittra, 1994; Hegde et al., 1980). Gadgil et al (2002) considered peanut yields of <500 kg ha^{-1} as crop failure. Basing on this criterion, simulated results here indicate crop failure occurred with all three systems during seven years out of 38 years due to very low and erratic rainfall. Crop failures would have been avoided with peanut/SD pigeonpea system in 7 years out of remaining 31 years, when yields were below 500 kg ha^{-1} with other two systems (fig 4). The higher yields simulated were mainly due to better yield of short duration pigeonpea that escaped water stress during critical stages (fig 5). Higher pigeonpea yields were simulated with peanut/SD pigeonpea system during 19 out of 31 years compared to peanut/MD pigeonpea due to escape of moisture stress mainly with flowering or pod filling stages in case of MD pigeonpea. However, in seven years, simulated SD pigeonpea experienced water stress during flowering that resulted in very low yields. These observations are made from the water stress reported in the simulation during pigeonpea growth phases. Simulations showed potential for yields >1.5 t ha^{-1} with peanut/ SD pigeonpea system in most of the good rainfall seasons.

Conclusions

We determined through simulation approach using APSIM, a combination of plant populations and row configuration for peanut/SD pigeonpea intercropping systems that would minimize crop failures in the water scarce environment by escaping terminal stress in many years. This system is also estimated to have good potential for higher yields in good rainfall seasons. Peanut/SD pigeonpea was further evaluated with farmers' participation in Anantapur region for determining its suitability during 2000-2002 crop seasons.

Two scientists from ARS, Anantapur received APSIM training at ICRISAT and software from APSRU, Australia for the purpose of exploring researchable issues in semi-arid Anantapur region.

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