Can profitable cropping systems be developed in the semi-arid tropics of Northern Australia?

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Summary. At two sites considered as representative of regions where dryland cropping expansion is proposed in the Australian semi-arid tropics, models for conventional maize and maize/legume pasture systems were used to assess the performance of rainfed cropping. Simulations showed that profitability was marginal and cropping was very risky in these regions. Adoption of an integrated crop/pasture system improves returns but, at world grain prices, not to a sufficent level to encourage cropping investment. This paper briefly samples the best estimates yet of the prospects of viable cropping in northern Australia.

Introduction

In the semi-arid tropics (SAT) of northern Australia, climatic and soil surveys have identified land with potential for cropping (2). As a consequence, there have been periodic occurrences of land clearing and investment in cropping enterprises in the Northern Territory (NT) and in north Queensland. Almost without exception, such investment has been unprofitable and short-lived. The question arises as to whether the potential for crop production is high enough for it to be viewed as a resource worth exploiting? In response to this question, research has been on-going in this climatic zone for more than 40 years. Therefore, the objective of this paper is to provide some conclusion to this question by quantifying the potential for dryland cropping of these marginal lands, and identifying management practices that provide the best compromise between economic returns and risk.

Realistic estimation of the potential for grainfed agriculture is extraordinarily difficult in a region where commercial experience has been relatively brief and climatic variability is extreme. In dealing with this dilemma, an operational research approach was implemented (5). One form of operational research is the use of simulation models in conjunction with historical weather data to predict yield probabilities for a site and hence expected economic returns and the associated risk. To date, crop simulation models of maize, sorghum, peanuts and kenaf have been developed, tested and applied in this climatic zone (1,2,5). In addition, models of a pasture legume and crop-pasture systems (3) have also been developed to assess the legume-ley cropping system proposed for this region (6,7). In this paper. the results of simulations for the long-term climatic record of representative sites in north Queensland and the NT are used to estimate the economic prospects of rainfed maize cropping in these semi-arid regions.

Methods

The simulation models

The AUSIM-Maize simulation model has been specifically developed and validated for dryland cropping in the SAT of northern Australia (1,2). The model simulates the growth of maize crops in response to climatic, soil and management conditions. Importantly. the effect of high soil surface temperature and soil water deficit on seedling establishment and of high temperature, water and N deficits on grain formation are also simulated.

A model of the cropping system proposed by McCown et a!. (6), where a legume pasture is grown in conjunction with a maize crop, has also been developed. This model simulates the growth of a Stylosanthes hamata (cv. Verano) sward on "build-up" rains at the start of a wet season. On a specified date, the killing of this initial pasture growth is simulated to form a surface mulch, after which a maize crop is planted no-till using nominated rainfall criteria. At maize emergence, the establishment of an understorey of volunteer legume from hard seed is simulated, and the growth of the maize crop and legume pasture intercrop are predicted under conditions where they compete for light, water and nitrogen during the remaining cropping season. The model simulates the effects of the initial pasture mulch on soil surface temperature and the effects of mulch decomposition over time on the soil N balance. A description of the models of the pure verano sward and of the maize/verano intercrop is given by Carberry et al. (3) for non-limiting N conditions. Routines to simulate N fixation by the verano and competition for N in the intercrop have since been added.

Predicted grain yield of maize and biomass yield of verano were close to observed yields for both intercrop and sole crop and pasture treatments (Fig. I). Data were collected from experiments where site, cultivar. sowing date, plant population. water regime and nitrogen fertility varied. Overall the root mean square deviation was 1082 kg/ha for predicted maize yield and 1005 kg/ha for predicted verano yield.

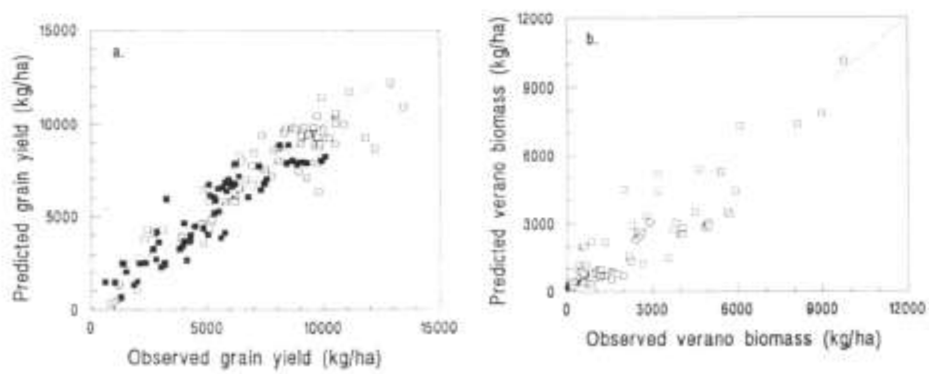

Figure 1. Predicted versus observed (a) oven-dry grain yields for maize grown either as a sole crop (o) or in experiments with a verano intercrop (n), Y =771.2+0.87X, R2=0.87, n=143; and (b) dry weight for verano grown as a pure stand and as an understorey to maize, Y =91.1+0.83X, R^2=0.81, n=78. The 1:1 (and fitted (- - - -) lines are also shown.

Model applications

Two simulation cases are explored in this paper. Firstly, rainfed maize yield was simulated for 80 years of climatic record at Mt Garnet (17.7S. 145.1E, 670m) in north Queensland and the 100 year record at Katherine (I4.5S, 132.3E,108m), NT. A matrix of plant populations and N fertilizer rates was simulated under conventional tillage systems at each site. Gross margins (GM, $/ha) for both sites were calculated using a maize price of $1 10/t, cost data relevant to Mt Garnet and a break-even return of $180/ha, representing estimated average fixed costs for cropping in this region. Greater detail of these analyses can be found in Carberry *et al. (2).*

In the second case, predicted yield for the maize/verano system was compared to conventional maize crops at Katherine. The maize crop was simulated at a sown density of 5 plants/m^2 and a fertilizer rate of 80 kg N/ha. The effect of including a legume ley in the the maize/verano crop rotation was reproduced by increasing the initial soil mineral N status of 20 kg/ha to 80 kg/ha (6). GMs were calculated using maize prices of $110/t (world price) or $280/t (NT import parity price), a verano hay price of $135/t and cost data available for the NT. GMs for verano hay were calculated as a substitute for returns from cattle grazing the verano pasture.

Both application cases used similar strategies as specified in previous risk analysis runs for this environment (1,2). Briefly, simulations treated each year independently. All parameters were re- initialized each year at the start of the wet season; soil water was reset to a dry profile. Maize plantings were instigated when a sowing criterion of 30 mm rainfall in a five day period was first met after 15 December each year. the date on which the killing of the verano mulch was specified in the intercropping system.

Results and discussion

The tradeoff between expected returns and the riskiness of different levels of resource management is compared for both sites using (E,.) space, in which mean GM returns *(E)* are plotted against their standard deviation of return *(s)* (Fig. 2). An (E,.) efficiency frontier is determined by joining points which had the highest GM for each given level of standard deviation. All resource combinations which fall below this "efficiency frontier" are less favourable combinations of returns and risk than those on it. Resource combinations falling on the frontier are equally risk-efficient and choice between them depends on attitude to risk. A decision-maker can trade-off higher returns for lower risk, or *vice-versa.* At Mt

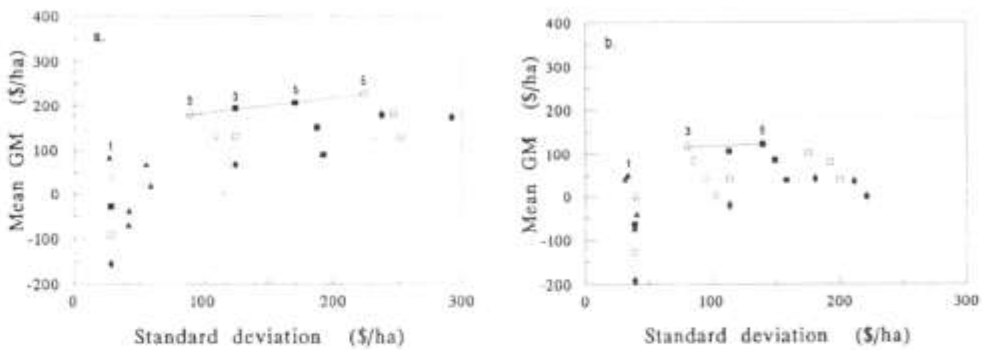

Figure 2. (E,s) spaces for maize at (a) Mt Garnet, Qld; and (b) Katherine, NT. Symbols refer to rates of N 0(•) 40(◊) 80(■) 120(□) 160(♦) kg ha^{-1}, numbers on the efficiency frontier (——) refer to plant densities (m^{-2}), and the proposed fixed cost (- - - - -) is shown.

Garnet, few risk-efficient strategies produced returns as high as fixed costs and their selection involved a high risk level. In contrast, at Katherine. only the lowest input strategies were risk-efficient and no strategy produced mean returns greater than the assumed level of fixed costs.

As conventional maize cropping appeared unprofitable at Katherine. the prospects of improving profitability by implementing an alternative legume Icy cropping system (6,7) were addressed. Simulations resulted in lower yield probabilities for a maize/verano intercrop compared to conventional maize if soil mineral N status was maintained at a low level (20 kg/ha) (data not presented). If the cropping of legume leys resulted in enhanced N status, then the probability of achieving high yield increased over conventional cropping but so did the probability of achieving low yield (Fig. 3a). At $110/t for maize and local costs, neither system resulted in profitable returns for the maize crop in any season (Fig 3b). However, in a cropping system integrated with cattle production, maize/verano production during the wet season resulted in returns greater than our break-even cutoff in 40% of seasons when the value of the volunteer legume pasture as hay was considered. Profitability increased markedly at the NT import parity price of $280/t for maize although failures still occurred in about I in 10 seasons (but the failure rate was 4 in 6 seasons during the run of dry years in the late 1980s!).

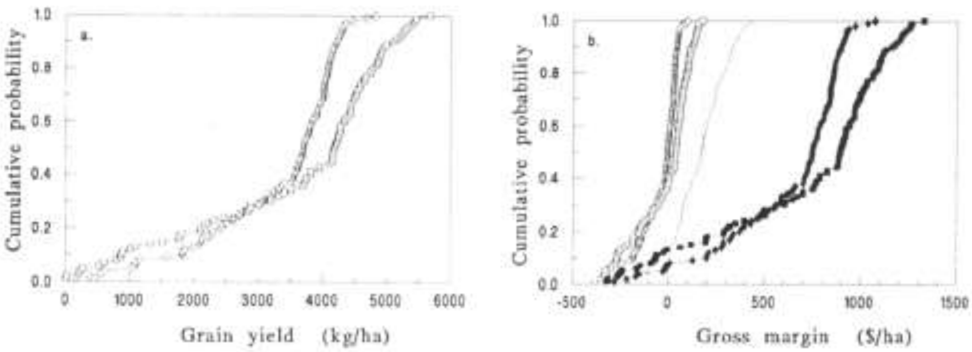

Figure 3. For maize grown at Katherine as a conventional crop (diamonds) or in an intercrop (squares), cumulative probabilities for (a) grain yield, and (b) GM, with prices of $110 [-l maize (hollow), $110 t-' maize + $135 t-' verano hay (—) or $280 t-' maize (solid), and fixed costs of $180 ha-^{1} (- - - -).

These analyses confirmed that profitability is marginal and cropping is very risky for dryland maize production on the red earth soils in the Mt Garnet and Katherine regions. Similar conclusions were reached when alternative crops to maize (sorghum. peanuts) were used in the analyses (2). Given the simulation results and the fact that Mt Garnet is close to the established agricultural infrastructure of the Atherton Tablelands compared to the small areas cropped in the NT, areas of north Queensland appeared a better, but not necessarily economically viable, proposition for dryland cropping than the Katherine region. Adoption of an integrated crop/pasture system at Katherine did improve GM returns but, at world grain prices, not to a sufficent level to encourage cropping investment. Clearly, however, returns from the current cropping of small areas to supply the local NT grain market have been sufficient to support a viable industry.

References

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