Integrating beef and cotton production reduces irrigation needs in the Texas Southern High Plains

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Introduction

The Texas High Plains is a semiarid agricultural region located in the central south plains of the United States. This area exemplifies semiarid regions where water is becoming scarce. Crop production depends heavily on irrigation primarily from the Ogallala aquifer at non-sustainable rates of use. Irrigated monoculture cotton (*Gossypium hirsutum* L.) is the dominant crop but grazing livestock in this once vast grassland is re-emerging as the aquifer declines. Environmental benefits of integrated crop and livestock systems have been suggested. We compared a cotton monoculture with an integrated cotton-forage-beef stocker steer system over 10 yr to determine effects on irrigation water use, profitability, and other measures of sustainability. Long-term systems research can reveal dynamic changes that short term studies fail to capture and can provide opportunities to improve ecosystem function and sustainability (Allen *et al*. 2008).

Materials and Methods

From 1999 to 2008, two, large-scale, subsurface drip irrigated systems (13 ha total area), with 3 replications in a randomized block design, compared water use, productivity, and economics of 1) a cotton monoculture, and 2) an integrated 3-paddock system that included cotton in a 2-paddock rotation with grazed wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) and a third paddock of perennial ‘WW-B. Dahl’ old world bluestem [OWB; *Bothriochloa bladhii* (Retz) S.T. Blake]) for grazing and seed production. Angus crossbred beef steers (*Bos taurus* L.; initial body weight = 229 kg; SD = 33 kg) grazed from January to mid-July.

Results and Discussion

Cotton yields, water, and chemical inputs

Cotton lint yield did not differ between systems (1,369 kg/ha). Over 10 yr, the integrated system used 25% less irrigation water, 36% less N fertilizer, and fewer other chemical inputs than the monoculture system (Allen *et al*. 2012). From May through September, irrigation plus precipitation replaced about 68 and 73% of ET_o for monoculture cotton and cotton in the integrated system, respectively. Grasses required about half the irrigation water/ha required by cotton. Within the integrated system, irrigation water applied to cotton, OWB, rye, and wheat was 422, 230, 201, and 135 mm, respectively (crop effect, $P<0.001$; SE = 5).

Animal performance

In January, steers began sequentially grazing OWB and rye followed by wheat, returning to spring growth of OWB by mid-May (Allen *et al*. 2012). WW-B. Dahl OWB provided almost three times more days for cattle grazing than rye but cattle grazed rye about twice as many days as wheat, measured either as days paddocks were occupied or as steer grazing d/yr. About 44% of the total days on OWB were during the winter dormant period with the remaining 56% during the active growth period during May, June, and July. Sequencing dormant OWB, rye, wheat, and spring OWB growth provided continuous grazing opportunities with an average of 185 d from January to termination of grazing in July with daily gains of 0.79 kg. Total gain system/ha averaged over 10 yr was 259 kg.

Soil effects

Benefits of the cotton/small grain rotation in the alternative system were seen in terms of reduced soil erosion (Collins 2003), increased diversity and numbers of soil microbial communities and increased soil organic C (Acosta-Martinez *et al*. 2010), greater potential for C sequestration (Fultz *et al*. 2011), and greater protection against soil-borne diseases (Allen *et al*. 2012). At the end of 10 yr, total C was higher in both the rotation and pasture of the integrated crop-livestock system (average across grazing treatments: 17.3 g/kg soil) compared to continuous cotton (11.4 g C/kg soil; Acosta-Martinez *et al*. 2010). Increased microbial biomass and enzyme activities of C, N, P and S cycling within the integrated system may represent positive changes in soil functioning compared to continuous cotton.

Energy

Total fossil energy use and associated C emissions were compared (Zilverberg *et al*. 2012). Energy efficiency of producing cotton lint (25 MJ/kg) was similar between the two systems. The integrated system’s OWB was more energy efficient at producing grazing days (32 MJ/animal/d) than the annuals wheat and rye (80 and 48

MJ/animal/d, respectively). Energy required by steers depended greatly on management of cows that produced these steers. As the aquifer is depleted and water is pumped from greater depths, the integrated system's lower water use will save increasing amounts of energy relative to the monoculture.

Allelopathy

Small grains crops, well known for allelopathic compounds, can play a role in weed control. Known allelopathic chemicals were detected in both rye and soil where rye grew, and appeared influenced by grazing (Li 2013). Grazing rye appeared to increase growth and productivity of both rye and the following cotton crop compared to caged areas where grazing of rye was excluded. Cotton planted into grazed rye had more plants/m of row and was taller until July than where grazing was excluded.

Economics

Economic viability of an agricultural economy is dependent on availability of soil and water resources and how these resources are allocated within production systems. Evaluation of the 2 production systems using mean input and output prices indicated that profitability over the 10-yr period was not different. During the first 4 yr, the integrated system was more profitable; however, over the last 6 yr of the project, the cotton monoculture became more profitable due largely to introduction of higher yielding cotton cultivars. Results indicate that where water availability is adequate, the cotton monoculture system has higher profitability than the integrated system. However, the integrated system could be a viable alternative where irrigation is limited due to aquifer depletion and/or pumping regulations (Johnson *et al*. 2013).

Conclusions

Over this 10-yr study, integrating crops, forages, and cattle reduced irrigation, chemical inputs, and soil erosion. Soil organic matter, C, and overall soil health were increased. Fossil fuel energy inputs were lower than the cotton monoculture system. Grazing reduced negative effects of allelopathy in the cotton-small grain rotation. Economically, the integrated system was a viable alternative where irrigation is limited and-or pumping regulations exist, and relative profitability will likely increase as water becomes more scarce. Systems research is expensive, time consuming, and labour intensive and requires time for complex interactions to be revealed. However, such long-term systems research establishes a platform for researchers to cooperate and explore the wealth of information available by blending their areas of expertise. Otherwise, vital information would go undiscovered. Through integrating crops and livestock, conservation of water can be achieved while providing other environmental benefits that go far beyond economic measures of success.

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