Using forages to conserve water in semi-arid irrigated cropping systems

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Introduction

The Texas High Plains are part of the largest, contiguously irrigated cropland in the USA, and draws water from the Ogallala aquifer. High crop prices, increased demand for maize for ethanol production, and severe drought have increased water depletion rates. Research has shown that integrating forages and grazing cattle into the cotton-dominant cropping system can reduce overall water use (Allen *et al*. 2012) while still offering farmers positive net returns (Johnson *et al*. 2013). Integrating forages with row crops also reduces needs for nitrogen (N) fertilizer, rebuilds soil organic matter (Acosta-Martinez *et al*. 2010), and reduces fossil energy use and associated carbon emissions (Zilverberg *et al*. 2012). Advances in irrigation delivery that minimize evaporation losses and the use of irrigation scheduling tools that factor in soil water availability and crop needs for evapotranspiration (ET) are keys to improving whole-system water use efficiency. The Texas Alliance for Water Conservation (TAWC) is a multi-disciplinary team of agricultural scientists, resource managers, and producers formed in 2004 to demonstrate tools and irrigation technologies for conserving water on commercial farms in the Southern High Plains of Texas. We report progress in demonstrating advances in water conservation in a region where production of forages and livestock can help alleviate the decline in ground water supplies used for crop irrigation.

Methods

Monitoring sites were established on 29-33 commercial farms (varied over years) in Hale and Floyd Counties, 50-80 km north of Lubbock, Texas, USA. Each farm-year combination was considered a representative of an agricultural system. The systems included crop monocultures (mostly cotton, *Gossypium hirsutum* L.), multi-crop systems (more than 1 species in a system, *e.g.* 1 irrigation circle could be allocated to different but separate crops), and integrated crop/livestock systems (*e.g.* 1 farm having a cropped field and a grazed field). One site was a beef cow/calf (*Bos taurus*) operation containing a diverse mixture of native and introduced grasses. Two sites comprised seed production of the perennial native grass, sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]. Hay was made from the residue after seed harvest. Data collection included monitoring of water pumped, measurements of ET and crop/livestock yields, and accounting for input and output costs and prices. Computer-based decision tools developed by TAWC were: (1) Irrigation Scheduling Tool for tracking crop water use during the growing season; (2) Contiguous Acre Calculator for calculating irrigation water availability for specific fields; and (3) Resource Allocation Analyzer for crop selection based on irrigation capacity and optimum inputs. Outreach and technology transfer involved face-to-face meetings, broadcast media, technical demonstrations at field days, and surveys of producer attitudes and willingness to change. All production and marketing decisions were made by the cooperating producers.

Results

Half of the sites in the program comprised monoculture cotton in 2005 (Table 1), and cotton was part of nearly every farm system defined as multi-cropping [*e.g.* cotton and grain sorghum, [*Sorghum bicolor* (L.) Moench, maize, or wheat (*Triticum aestivum* L.)] and integrated crop/livestock throughout the 7 years. The grass seed crop consisted of two production fields. One beef cow-calf producer participated from 2005-2010, but then withdrew because of retirement. Two producers grew monoculture maize in 4 of the years to take advantage of high grain prices. Land allocation to the various crops varied from year to year according to producer decisions based largely on commodity prices and availability of irrigation.

Nitrogen fertilizer application averaged 59 kg/ha on the beef pasture, which was considerably lower than the irrigated crop fields (Table 2). The two most profitable systems, when expressed on the basis of irrigation volume

Table 1. Distribution of agricultural systems in TAWC demonstration project in the Southern High Plains of Texas, USA, by producer number and land area participation in 2005 and 2011.

Agricultural system	Producer participation		Land area participation	
	2005	2011	2005	2011
	(%)	(%)	(ha)	(ha)
Multi-cropping	50	46	885	815
Cotton monoculture	27	29	285	459
Integrated crop/livestock	11	11	217	256
Grass seed and hay	8	7	77	77
Beef cow/calf pasture	4	0	255	0
Maize monoculture	0	7	0	57

Table 2. Mean nitrogen fertilizer and water applied and net returns per unit of water applied in TAWC agricultural systems in the Southern High Plains of Texas, USA, averaged over 2005-2011.

Agricultural system	Nitrogen applied	Irrigation applied	Net returns on water
	(kg/ha)	(mm)	(US$/m^3)
Multi-cropping dryland	16	0	-
Multi-cropping irrigated	144	362	0.16
Cotton monoculture dryland	0	0	-
Cotton monoculture irrigated	123	298	0.20
Integrated crop/livestock	124	293	0.16
Grass seed and hay	141	287	0.54
Beef cow/calf pasture	59	128	0.35
Maize monoculture	256	453	0.17

applied (US$/m^3), were grass seed/hay and the beef cow/calf pasture, resulting in US$0.54 and US$0.35, respectively, compared with US$0.16 to US$0.20 for the other systems (Table 2). The grass seed/hay system was highly profitable despite high use of nitrogen and irrigation, due to severe droughts that caused high prices for native grass seed and hay. The beef pasture system was profitable owing to favourable cattle prices and low use of nitrogen and water.

The TAWC project has promoted technologies that conserve irrigation water for crop production. The project web site (www.tawcsolutions.org) has logged 417 different users of the online decision-support tools, of which at least 14 were from outside of Texas. There has been a shift from furrow systems, which have substantial evaporation losses, to low-elevation sprinkler and subsurface drip systems, which minimize losses and improve crop water use efficiency. Interviews and surveys indicated that the project increased farmers' understanding of monitoring ET and water availability, thereby improving water conservation.

Conclusions

Forages seed crops with hay and cattle grazing reduced water use and yielded the greatest net returns per unit of irrigation water used. Forage and grazing systems are viable alternatives to traditional row crops in semi-arid environments where irrigation is in decline. Moreover, forage systems contribute environmental benefits that promote long-term agricultural and soil sustainability. The TAWC project provides a model for other water-limited environments to promote farmer adoption of water-conserving technologies.

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