ABSTRACT: Grazing forages on small-grain fields can be a profitable “second crop” for grain producers and an opportunity for cow–calf producers to retain ownership of weaned calves. The increasing costs of conventional tillage and movement of soil nutrients into surface water creates a need for more sustainable production practices to be incorporated by producers into wheat pasture production systems. Research at the Livestock and Forestry Research Station near Batesville, AR, and the Southwest Research and Extension Center near Hope, AR, has been conducted over a 9-yr span to characterize the impacts of pasture systems on forage production, animal performance, soil quality, water runoff, and the economics associated with the stocker cattle enterprises. Gains of growing cattle grazing nontoxic endophyte-infected tall fescue and small-grain forages can be increased by 80 and 150%, respectively, compared with grazing Bermuda grass or toxic endophyte-infected tall fescue. Producers grazing spring-calving cowherds can use these improved forages to accelerate stocker performance when retaining calves in the fall and improve net returns by 99% with winter annual or nontoxic tall fescue production systems compared with Bermuda grass or toxic tall fescue. Rainfall simulation of small grain pastures indicates that runoff volume and nutrient load does not differ between conventionally tilled fields and no-till fields in the spring before tillage when soil surface cover is similar. In the fall after tillage, however, conventionally tilled fields had 4 times greater runoff; hence, there was 1.9 times greater N runoff and 3.2 times greater P runoff in conventionally tilled fields compared with no-till. Total natural rainfall runoff from conventionally tilled wheat fields were 2 times greater than from no-till fields with 25 mm rainfall events yet were 4 times greater with 62-mm rainfall events. Soil analysis shows that soil aggregate content was greater in no-till compared with conventional till, indicating greater soil porosity, improved water infiltration rate, and reduced erositivity of soil. Carbon concentration in no-till soils was 50% greater than conventional tillage after 9 yr. These experiments show that production systems can be designed that maintain livestock production, increase soil quality, reduce nutrient discharge, and promote improved economic returns.

Key words: economics, growing cattle, pasture, runoff, soil quality
profitability in Southeastern beef production lies in stockering weaned calves on high quality, cool season annual or perennial pastures.”

The enterprise services that the stocker-cattle segment supplies to the beef industry are well characterized. These services include providing the market with immunocompetent weaned feeder cattle that have been acclimatized to feed bunks and water sources and have been grouped in load lots; other services include providing placement area for calf numbers that are in excess of feedyard capacity at times of the year when large numbers of calves are marketed. Troxel and Barham (2012) report that 75% of calves in Arkansas are marketed as individuals, but marketing cattle in groups increased the sales price by 4%. Troxel and Barham (2012) also indicate that 20% of calves marketed in Arkansas are USDA Muscle Score 2 or less whereas Reuter et al. (2011) found that 37% of calves purchased as Muscle Score 2 would have been a Muscle Score 1 at slaughter, indicating these calves were unfairly discounted when purchased. Even though these services add profitability to the stocker enterprise, net returns are dependent on performance and the costs of production. Recently, as cost of BW gains during finishing have increased 85% from 2000 to 2011 (Waggoner, 2012), the value of BW gain (USDA, 2012) for stocker calves has increased by 134% from the annual average value of BW gain of approximately $50/45.4 kg in 1990 to 2000 to $111/45.4 kg in 2011, indicating an increase in the profit potential of stocker programs (Fig. 1).

Wheat forage for dual use cropping and livestock production is primarily established using conventional prepared seedbed methods (Anders et al., 2010), resulting in residue covers of ≤10% (Bowman et al., 2008). Conventional establishment methods reduce soil quality and C concentration (Anders et al., 2010) and decrease profitability through increased costs and variability of production (Watkins et al., 2011).

Alternatively, no-till technologies have been shown to improve soil quality and sequester soil C (Anders et al., 2010), increase net returns, and decrease monetary risk (Watkins et al., 2011) with little impact on animal production (Bowman et al., 2008; Morgan et al., 2012). Consequently, production systems need to be identified that improve economic returns and reduce environmental impacts of stocker cattle enterprises. The purpose of this review is to discuss the current state of the stocker industry and illustrate research conducted to improve its sustainability.

STOCKER CATTLE PRODUCTION SYSTEMS

Stocker cattle research conducted from 1999 to 2009 at the University of Arkansas Southwest Research and Extension Center (33°42′ N, 93°31′ W, and elevation 107 m) near Hope in southwestern Arkansas and the University of Arkansas Livestock and Forestry Research Station near Batesville, in northern Arkansas (35°50′ N, 91°48′ W, and elevation 150 m) was compiled to characterize the effects that grazing season and forage species have on animal performance and net returns to stocker cattle enterprises. Research conducted with growing cattle grazing warm-season grass (WSG) pastures or WSG with supplementation (WSG+S) are reported in Gadberry et al. (2009, 2010) and Beck et al. (2011a,b), cool-season annual (CSA) pastures are reported in Beck et al. (2005, 2008), Bowman et al. (2008), and Morgan et al. (2012), and toxic tall fescue (TF) or nontoxic tall fescue (NF) pastures are reported in Beck et al. (2008, 2009). This data set included 3,288 growing cattle (n = 185 heifers and 3,103 steers) with average initial BW ± SD = 234 ± 29.6 kg. The description of animal populations used in each experiment is described in the respective citation, but all animals used were of predominantly beef breeding and were from English or Continental breeds of origin. Forages sampled from pastures during these experiments were analyzed for CP, NDF, and ADF using near-infrared reflectance and TDN content was calculated based on equations developed in Arkansas reported in Davis et al. (2002).

Forage Characteristics and Nutritive Quality

Forages sampled from pastures used in the studies [reported by Gadberry et al. (2009, 2010) and Beck et al. (2011a, 2012b) for WSG, Beck et al. (2005, 2008), Bowman et al. (2008), and Morgan et al. (2012) for CSA, and Beck et al. (2008, 2009) for TF and NF] were analyzed for CP, NDF, and ADF using near-infrared reflectance and TDN content was calculated based on equations developed in Arkansas reported in Davis et al. (2002).
Warm-Season Grass Pastures. In the southeastern United States, warm-season forages are the basis of beef production. Yet these pastures are affected by variable growing conditions, including annual and seasonal droughts, which limit forage production and animal performance. In the early summer (May and June) the NDF and ADF concentrations (64.2 ± 5.9 and 33.9 ± 6.2% of DM, respectively) and CP concentration (16.3 ± 5.0% of DM) would not be expected to limit DMI or performance of growing cattle. Calculated TDN values averaged 70.1 ± 10.1% (DM basis), which, based on NRC (1996) estimates of NEm and NEg, would be adequate for ADG in excess of 1 kg/d. As the summer progressed, seasonally hotter and drier conditions caused increased fiber concentrations and decreased CP concentrations. Acid detergent fiber concentration increased to 37.0 ± 1.4% in July and 36.5 ± 5.0% in August, and NDF concentrations increased to 69.7 ± 1.9% in July and 73.5 ± 1.1% in August. In September, rains and cooler temperatures resulted in reductions in both ADF (33.5 ± 1.4%) and NDF (70.1 ± 3.6%) concentrations in September. The increased fiber concentrations of mid- and late-summer forages reduced energy availability so that estimates of animal performance (NRC, 1996) were limited to 0.67 kg/d in July, 0.54 kg/d in August, and 0.76 kg/d in September. Crude protein concentration was not a limiting factor in animal performance averaging 12.6 ± 2.3, 11.6 ± 2.2, and 13.1 ± 3.1%, respectively, for July, August, and September. Crude protein concentration was at minimum 146% of NRC (1996) requirements for steers gaining 0.91 kg BW/d. Moore et al. (1999) stated that supplementation resulted in positive associative effects when the forage TDN to CP ratio was >7:1 whereas negative associative effects would be expected from supplementation when the ratio was <7:1 in the forage. The TDN:CP ratio in the introduced warm-season grasses in these pastures ranged between 4:1 and 5:1 during this experiment indicating that DE content of the forage, not CP, is the limiting factor for growth.

Tall Fescue Pastures. Most cool-season perennial grasses are short lived in the lower southeastern United States (Gunter and Beck, 2004), but tall fescue [Lolium arundinaceum (Schreb.) S.J. Darbysh. = Festuca arundinacea Schreb.] infected with the naturally occurring endophyte [Neotyphodium coenophialum (Morgan-Jones & Gams.) Glenn, Bacon, & Hanlin comb. nov.] has the benefit of improved persistence (Gunter and Beck, 2004). Although TF is of high nutritive value during the autumn and early spring (Beck et al., 2008, 2009), the performance of grazing livestock is often limited by fescue toxicosis (Gunter and Beck, 2004). Endophyte-free tall fescue produces excellent animal performance (Beck et al., 2009), but stand life is limited in the southeastern United States (Gunter and Beck, 2004; Beck et al., 2009). Numerous experiments have proven that NF is persistent and promotes excellent cattle performance (Beck et al., 2008, 2009).

Detergent fiber and CP concentrations in tall fescue whether TF or NF increased from the start of grazing in November through the winter. With the start of spring regrowth, detergent fiber concentrations increased and CP concentrations decreased, which is associated with increased forage maturity during the late spring in the tall fescue grazing experiments reported in Beck et al. (2008, 2009). Although changes were observed in CP concentrations and energy estimates during the grazing experiments, in most cases energy and CP concentrations were greater than the requirements for a 250-kg growing steer to gain in excess of 1.20 kg of BW/d (70% TDN and 12.4% CP; NRC, 1996) until the end of the spring grazing season in late April or early May of each year. These cool-season perennial grasses provide a nutrient dense diet for grazing cattle indicating any differences in animal performance would likely be due to the anti-quality factors associated with fungal endophytes in TF.

Cool-Season Annual Pastures. In the fall and early spring, cool-season annual grasses planted into dedicated crop fields (Beck et al., 2005; Bowman et al., 2008; Morgan et al., 2012) or interseeded into warm-season grass sod (Beck et al., 2007, 2008, 2011b) have been used extensively for grazing stocker cattle to improve net farm income in the High Plains and southeastern United States. Improvements in net income are achieved with the availability of high-quality forages at a time of year when weaned cattle are at a seasonally low price and other predominant forages are dormant and of low nutritive quality (Beck et al., 2005). Cool-season annual grass forages are extremely high in CP (>25% DM basis; Beck et al., 2007; Bowman et al., 2008; Morgan et al., 2012) and low in fiber (40 to 49% NDF and 19 to 29% ADF, DM basis; Beck et al., 2007; Bowman et al., 2008; Morgan et al., 2012) during the fall and early spring before stem elongation. Even though increases in fiber concentration (increasing to over 50% NDF) and reductions in CP concentrations (decreasing to 20% DM basis) were noted in each experiment during April and May, CP content and estimated energy content of the forages were greater than animal requirements for a 250-kg growing steer to gain in excess of 1.20 kg BW/d (NRC, 1996) until the end of the spring grazing season each year. This indicates that CSA provide a nutrient-dense diet for grazing cattle and any differences in animal performance are likely due to restrictions in forage availability (Gregorini et al., 2011).

The forage DM production of cool-season annual grasses follows a biphasic production curve, in which productivity during the fall and winter is at a much
lower level than during the spring (Beck et al., 2007; Bowman et al., 2008; Morgan et al., 2012). Therefore, stocking rates should be much less in the fall and winter from early November to late February (1.9 to 3.7 calves/ha; Beck et al., 2007; Bowman et al., 2008; Morgan et al., 2012) than in the spring from late February to early May (4.9 to 7.4 calves/ha; Beck et al., 2007; Bowman et al., 2008; Morgan et al., 2012). Stocking rate is a fundamental variable for managing pastures and there is a distinct relationship between stocking rate and animal performance for each forage type (Bransby et al., 1988). To determine the forage allowance that would result in the optimal stocking rate for fall and winter grazing of cool-season annual pastures, the forage production and steer performance from the experiments reported by Bowman et al. (2008) and Morgan et al. (2012) were used to determine the response of ADG to the independent variable of initial forage allowance (kg forage DM/kg BW) using a segmented model (SAS/STAT; SAS Inst. Inc., Cary, NC). The response of ADG to forage allowance was fit and joint point estimated using the NLIN procedure of SAS. This dataset used pasture means for cattle grazing small-grain pastures during the fall and winter from 2003 to 2009 and included 117 records. In this analysis, the average forage allowance during the fall and winter ranged from 0.8 to 8.2 kg of forage DM/kg average BW and the response of ADG to the average forage allowance (average kg forage DM/kg average BW; Fig. 2A) indicates that the maximum ADG is expected at 3.5 kg forage DM/kg average BW with 1.24 kg/d. It is interesting to note that an ADG of approximately 0.9 kg/d would be expected if forage allowance of approximately 1.8 kg forage/kg BW. This level of performance (0.9 kg/d) is the level that many stocker producers set as the goal for the period of stocker cattle ownership, which allows the fixed and variable costs of stocker ownership to be spread over multiple units of gain.

Managers are faced with decisions regarding stocking rate at the beginning of the grazing season with only the forage produced up to that point to consider in setting the stocking rate. Analysis of the forage DM available at turnout in these experiments indicates the initial forage DM yield is highly correlated with average forage DM yield ($r = 0.94$), so the analysis was conducted only considering the initial forage allowance (kg initial forage DM/kg initial BW) on ADG during the fall and winter (Fig. 2B). The response of ADG to the initial forage allowance indicates that a maximum ADG of 1.24 kg/d could be expected at 5.0 kg forage DM/kg initial BW and ADG of 0.9 kg/d could be expected at an initial forage allowance of approximately 2.4 kg forage DM/kg initial BW.

Animal Performance

Raw data from the research conducted with growing cattle grazing WSG and WSG+S pastures (Gadberry et al., 2009, 2010; Beck et al., 2011a,b), CSA pastures (Beck et al., 2005, 2008; Bowman et al., 2008; Morgan et al., 2012), and TF and NF (Beck et al., 2008, 2009) was compiled. These data were analyzed as a randomized complete block design using a mixed models procedure in SAS using year × experiment as the random element and forage system as the fixed element. In addition, the performance of calves grazing TF, NF and CSA in both the fall and spring were used to parameterize the model. Cattle grazing WSG pastures were either unsupplemented or supplemented (WSG+S) with either a cottonseed byproduct supplement (Gadberry et al., 2009) or dried distillers grains supplement (Gadberry et al., 2010; Beck et al., 2011a,b). Cattle grazed WSG and

![Figure 2.](image-url)
WSG+S pastures for an average of 95 ± 12 d, CSA for 69 ± 4 d, TF for 80 ± 5 d, and NF for 89 ± 5 d. Providing supplement to cattle grazing summer pastures (WSG+S) increased ($P < 0.01$) BW gain (Fig. 3A) and ADG (Fig. 3B) compared with WSG alone. As stated previously, the nutritive quality of WSG is not sufficient to produce satisfactory animal performance without appropriate supplementation. Body weight gain (Fig. 3A) and ADG (Fig. 3B) were not different ($P = 0.85$) for growing cattle grazing TF and WSG based pastures (41 ± 5.5 kg/calf and 0.52 ± 0.05 kg/d, respectively, for TF and 44 ± 14.1 kg/calf and 0.52 ± 0.12 kg/d, respectively, for WSG), yet both were less ($P \leq 0.05$) than BW gain and ADG of cattle grazing WSG+S, NF, or CSA. Body weight gain of WSG+S (70 ± 14 kg/calf) and CSA (70 ± 5.5 kg/calf)

![Figure 3](image-url)

**Figure 3.** Effect of stocker production and forage system on animal performance (BW gain per calf, Panel A; ADG, Panel B) and economics (total cost per hectare, Panel C; cost of BW gain, Panel D; net return per calf, Panel E; and net return per hectare, Panel F) of the stocker cattle enterprise. Within each panel, bars having different letters differ ($P < 0.05$). WSG = warm-season grass; WSG+S = WSG with supplementation; TF = toxic tall fescue; NF = nontoxic tall fescue; CSA = cool-season annual.
did not differ ($P = 0.98$) and were less ($P < 0.01$) than observed with NF (79 ± 5.5 kg/calf) even though ADG of calves grazing CSA (1.01 ± 0.05 kg/d) were greater ($P < 0.01$) than NF (0.91 ± 0.05 kg/d), which was greater ($P < 0.01$) than WSG+S (0.79 ± 0.11 kg/d). Body weight gains of growing cattle in WSG+S, NF, and CSA are accelerated compared with WSG and TF, indicating that targeted supplementation and improved forage varieties are capable of increases in production. But the question remains: Is the added cost of using these production technologies cost effective and beneficial to net returns of the stocker cattle enterprise?

**Economics of Stocker Cattle Production Systems**

Economic indicators such as total cost of production per hectare, cost of BW gain, net return per calf, and net return per hectare were based on costs of production reported in Beck et al. (2012a) for cattle grazing WSG pastures with supplementation cost of $0.33/kg for byproduct feeds. Enterprise budgets reported by Watkins et al. (2011) were used to determine returns of cattle grazing CSA, and budgets reported by Beck et al. (2008) were used to determine costs for cattle grazing TF and NF pastures. Fertilizer costs were adjusted to reflect current cost of $1.43/kg actual N. Mineral supplementation was charged at $0.72/kg ($0.09/calf per day). Receiving, marketing, and transportation costs were charged at $25/calf (Beck et al., 2008). The value of gain was standardized using the 2011 annual average of $2.02/kg to remove any bias associated with seasonal fluctuation commonly observed in feeder cattle prices and value of BW gain.

Calves grazing WSG were less ($P < 0.01$) profitable per calf (Fig. 3E) and per hectare (Fig. 3F) than WSG+S even though total cost of production per hectare (Fig. 3C) was greater ($P < 0.01$) for WSG+S. Although a high feed cost of $0.33/kg was used in this analysis, the addition of a mid-protein (25 to 30% CP), digestible fiber based byproduct supplement (dried distillers grains and cottonseed cake in these studies) improved net returns per calf compared with WSG alone because supplementation provided sufficient improvements in animal performance so that cost of BW gain did not differ. This later fact makes the point that minimizing cost of production to the detriment of animal performance will usually result in reduced net returns; therefore, the goal of managers should be to optimize cost of production and wisely determine the most cost effective inputs that should be used to enhance animal performance.

Likewise, even though the ADG (Fig. 3B) of cattle grazing CSA was greater ($P < 0.01$) than other forage production systems, the total cost of production per hectare (Fig. 3C) was greatest ($P < 0.01$) as well whereas the least ADG and BW gain per calf were observed with WSG, the production system with the lowest cost/hectare ($P < 0.01$). Toxic fescue cost/hectare was intermediate ($P ≤ 0.02$) between WSG+S and NF and had very low animal performance (Fig. 3A).

Cost per kilogram of BW gain (Fig. 3D) did not differ ($P = 0.64$) across production systems because the lowest cost production systems tended to have lower animal production. Interestingly, the production systems with greater cost of production within each production season (WSG+S, TF, and CSA) had numerically ($P ≤ 0.34$) lower cost of BW gain than less productive systems.

Net return per calf (Fig. 3E) was least ($P < 0.01$) for TF and WSG systems. Net return per calf tended ($P = 0.10$) to be greater for CSA compared with WSG+S and was greater ($P < 0.01$) for NF than CSA. Net return per hectare was greater ($P < 0.01$) for NF compared with CSA, which was greater ($P < 0.01$) than the other forage production systems. Beck et al. (2008) reported that annual establishment costs resulted in greater cost of production and reduced net returns of the CSA production system compared with NF. Nontoxic tall fescue allows for adequate animal performance and reduced costs of production if the stands can be managed for persistence (Gunter and Beck, 2004). It is apparent from this analysis that minimizing total cost of production does not necessarily lead to increased net returns, especially if the increased total cost of production creates a situation in which animal production is improved economically.

**CHANGING PRODUCTION SYSTEMS IN THE COOL-SEASON ANNUAL STOCKER ENTERPRISE**

Interest has grown worldwide in systems for integrated cropping and livestock production (Moore, 2009; Hilimire, 2011). Production of livestock on the same land units as grain cropping in subsequent seasons helps supply societal demands for food production (Hilimire, 2011). Inclusion of no-tillage (also known as direct seeding) technology can have advantages of both reduced production risk and economic risk (Watkins et al., 2011), improved grazing efficiency (Gregorini et al., 2011), and improved environmental sustainability (Anders et al., 2010) compared with conventional clean tillage production practices. Hence, the remainder of this review will discuss research efforts conducted with small grain establishment methods and their effect on production, economics, and environment.
Tillage Systems for Establishment of Cool-Season Annual Pasture

As reported by Bowman et al. (2008) and Morgan et al. (2012), small-grain pastures were established in the first week of September of each year using 1) conventional tillage (CT), 2) no-till (NT), or 3) light disk (LD). Conventional tillage consisted of chisel plowing each treatment field twice followed by disking twice with a cutting disk to incorporate any plant material and fertilizer or lime into the soil. The field was then disked twice with a finishing disk before planting. Fields were sown in 17.8-cm rows to a 2.5 cm depth. Residue cover of CT fields was <5% at planting. Fields in NT were prepared using summer chemical fallow by applications of 4.68 L/ha of glyphosate [N-(phosphonomethyl) glycine; Roundup Original Max; Monsanto Co., St. Louis, MO] during the summer in early June and in late August before planting for annual grass and weed control followed by direct seeding into the stubble of the previous season using a 3.7-m grain drill (model 750; Deere and Co., Moline, IL) in 17.8-cm rows to a depth of approximately 2.5 cm. Surface residue cover was targeted at >85%. In LD, fields were subjected to summer chemical fallow as described for NT and established by disking once with a finishing disk to disturb the soil surface residue to a target of 50% residue cover at the time of seeding. A conventional fertilizer spreader was used to broadcast seed after disking; fields were then harrowed once to cover the seed.

Conventional tillage practices have several shortcomings that limit cost effectiveness and sustainability. First, CT requires repeated passes with several specialized pieces of high-horsepower equipment and high tractor horsepower requirements, thereby using large amounts of labor and fuel (Watkins et al., 2011). Second, CT creates large amounts of soil disturbance, decreasing soil C content and increasing potential for runoff of precipitation and loss of soil nutrients. Although equipment requirements are less, NT also requires a specialized drill to penetrate through surface residue for seed placement. The LD treatment may be the most easily implemented by producers with low capital availability for equipment and operating costs because of reduction in the amount of tillage equipment required along with lowest fuel and labor requirements.

Effect of Tillage System on Forage Production and Animal Performance

Forage production is quite variable from year to year and there is a large influence of the climatic conditions on forage production in the different establishment methods. Over the 8 yr in which these establishment methods were studied, fall forage accumulation before turnout of calves in November was similar for all treatments in 3 yr; NT produced more forage than CT in 2 yr and produced more forage than LD in 3 yr whereas CT produced more forage than NT in only 1 yr and LD in 2 yr. The conservation tillage techniques (NT and LD) studied were as effective as CT in establishing small grain pastures and may provide the best alternative in many situations.

When compared with NRC (1996) requirements for growth of steers gaining 0.9 kg/d or greater, wheat pasture often offers excessive CP and digestible energy. Therefore, forage mass is usually considered the limiting factor for growth rate of cattle grazing wheat pasture (Bowman et al., 2008; Morgan et al., 2012). The forage mass data from these studies indicate that conservation tillage techniques (LD and NT) produce adequate forage for stocker cattle production. Morgan et al. (2012) reported that as stocking rate increases residual forage DM decreases linearly for all establishment methods, yet at greater stocking rates NT had greater forage mass than CT. When the animal performance data reported by Morgan et al. (2012) was evaluated by year, there was no effect of establishment method on performance of steers grazing during the fall and winter for 3 yr; steers grazing NT pastures at the greatest stocking rate gained more BW during the fall in 1 of the 4 yr. Interestingly, during the spring grazeout, steers grazing NT fields that had been stocked at the greatest rate in the fall had greater animal BW gains during the spring in 3 out of the 4 yr. The increased forage mass in NT at the greatest fall stocking rate and greater animal performance during the spring compared with CT is indicative of advantages in NT related to forage regrowth potential under heavy stocking pressure. No-till fields have the benefit of more surface residue, which may have created a firmer soil surface as observed by Bowman et al. (2008), which would help to mitigate hoof damage from traffic that can cause stand depletion in CT fields. The increase in spring grazeout performance in high stocking rate NT fields may also be partially related to changes in animal foraging behavior. Gregorini et al. (2009) found that wheat plants established using NT had more upright plant architecture than CT or LD, which provided for greater bite mass and greater instantaneous intake rate.

Economics of Tillage Systems

Tillage system had an impact on animal performance in the experiment reported by Bowman et al. (2008) when the fall forage growth was limited by lack of timely rainfall. In this experiment, NT establishment of small-grain forages for stocker calves was superior to CT and LD practices when fall rains were delayed because soil water profile could be maintained by summer chemical
fallow. Establishment of small-grain pasture with NT and LD techniques was as successful as CT practices when timely fall rains promoted emergence and growth in all systems. Therefore, practices such as NT should reduce weather-related risks for stand establishment and forage production, which should provide built-in economic advantages for stocker cattle producers.

Two studies evaluated the economics of stocker cattle grazing on NT and LD winter forage. In the first study, Anders et al. (2007) used partial budget analysis to evaluate the average profitability of grazing stocker steers on soft red winter wheat and rye forage planted with conservation tillage methods in Arkansas. Steer BW gain and forage production data from 3 yr of research at the University of Arkansas Livestock and Forestry Research Station for the period from 2003 through 2006 were used to calculate stocker grazing returns to CT, LD, and NT forage production. The NT system was the most profitable of the 3 systems ($171/ha) followed by the LD system ($99/ha). The CT system had a negative average return over the 3-yr study period ($49/ha). Lower forage production costs and greater fall BW gains were cited as the primary reasons for greater profitability of the conservation tillage systems (NT and LD) relative to the CT system.

The second study evaluated both profitability and return variability of grazing stocker steers on CT, LD, and NT wheat pasture using simulation and stochastic dominance analysis (Watkins et al., 2011). This study was based on 7 yr of data from the Livestock and Forestry Research Station for the period 2003 through 2009. The results indicate both NT and LD were more profitable on average and less variable in returns than CT. The LD system dominated the CT system by second degree stochastic dominance, implying risk-averse cattle producers would prefer LD over CT. The NT system dominated the CT system by first degree stochastic dominance, implying both risk-averse cattle producers and cattle producers desiring more income to less would prefer NT over CT. Both systems had larger probabilities of receiving positive returns than the CT system. Based on 500 simulated iterations of net returns for each system, the NT system had the greatest probability of receiving a positive return (75%) followed by the LD system (61%). Alternatively, the CT system had a positive net return less than half the time (44%). This analysis indicated that both NT and LD establishment methods were more profitable and were preferable to producers desiring reduced risk.

### Impact of Tillage on Soil and Water Quality

#### Rainfall Simulations

To evaluate the impact of tillage on soil and water quality, 2 rainfall simulations were conducted in the fields used for the wheat pasture establishment study. These rainfall simulations were conducted as described by Humphry et al. (2002), in which plots (1.5 by 2 m) were placed in areas of each pasture replication with representative slopes and residue cover and a single nozzle was centered at a height of 3 m, which was operated at a pressure of 28 kPa with continuous flow capable of producing a simulated rainfall event at an intensity of 70 mm/h. Runoff volume, turbidity, particulate load, and the nutrient content of runoff water and solids were measured. A single rainfall simulation will indicate the erosion potential of a field at a given point in time; therefore, the initial simulations were conducted in the fall of 2005 after planting but before small-grain seedling emergence. The initial simulation was may be biased to the NT treatments because of the dry soil conditions. So, a second rainfall simulation was conducted in the early spring of 2010 after the winter rains when soils were saturated.

The results of the rainfall simulation experiments are presented in Table 1. Residue cover in the fall was greater ($P < 0.05$) for NT than LD and CT and was also greater for LD than CT. In the fall, total runoff volume was nearly 4 times greater for CT than NT and was nearly 2 times greater for CT than LD. The amounts of total solids and nutrient flows followed the same trends as total runoff volume in the fall. Total solids were over 10 times greater for CT than NT and were over 6 times greater for CT than

<table>
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<th>Item</th>
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<td>0.001</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>0.016</td>
<td>0.003</td>
<td>0.020</td>
<td>0.001</td>
</tr>
<tr>
<td>Nitrate N, kg/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2005</td>
<td>0.353</td>
<td>0.609</td>
<td>0.084</td>
<td>0.001</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>0.015</td>
<td>0.006</td>
<td>0.014</td>
<td>0.001</td>
</tr>
<tr>
<td>Total P, kg/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2005</td>
<td>0.101a</td>
<td>0.171a</td>
<td>0.604b</td>
<td>0.001</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>0.031</td>
<td>0.015</td>
<td>0.042</td>
<td>0.001</td>
</tr>
</tbody>
</table>

1Rainfall simulation conducted after planting before emergence of wheat seedlings in September 2005 and before placement of steers on pasture for the spring grazeout period. Least-squares means were separated using the least significant difference procedure.
Ammonia and total P content of the runoff was also 3.7 and 6 times greater for CT than NT.

In CT, the ground cover during the spring was much greater than in the fall as would be expected with the forage growth over the winter; however, there was still greater ground cover in NT and LD than CT at that time. Because soils were at the water saturation point and the increased ground cover had the ability to slow down runoff, there were no differences in total runoff volume or nutrient content of runoff. Nevertheless, there were still more total solids in runoff from CT than NT indicating that erosion potential of CT fields was still greater during the spring. The data from the rainfall simulations indicate that conservation tillage (NT and LD) provided benefits in reduced runoff and reduced nutrient flows compared with CT. Although rainfall simulations provide a good estimation of potential runoff and erosion, they will not provide values for annual runoff, sediment loss, and nutrient movement; therefore, total rainfall runoff collections were initiated in the 2005 to 2006 crop year.

**Total Rainfall Runoff Collection.** Although rainfall simulations provide a good estimation of potential runoff and erosion, they do not provide values for annual runoff, sediment loss, and nutrient movement. Annual measurements of these parameters provide insight into the impact of cattle grazing and allow the development of models that will better predict soil, water, and nutrient losses at a watershed level. To achieve this, flow meters and sediment collection devices were installed at the bottom of 3 fields (1 of each tillage treatment), which provided the ability to monitor water, soil, and nutrient movement off the field throughout the year for the duration of the project.

Runoff measurements collected during the 2005 to 2006 crop year were regressed by the 24-h accumulated rainfall for each precipitation event (Fig. 4). The runoff from CT fields was best explained ($R^2 = 0.72$) by a quadratic formula, which indicates that runoff began to occur at very low rainfall amounts. This runoff at low rainfall levels corresponds to observations at the research site of soil sealing off and soil resistance to infiltration of water. Runoff volume in CT fields then decreased as additional rain softened soil surface crust and water began to infiltrate into soils. As additional precipitation fell and soils became saturated, runoff volume again increased. Runoff from NT and LD were best explained ($R^2 = 0.51$ and 0.63, respectively) by linear models, which indicate that little to no runoff occurred until the rainfall event reached $>20$ mm. Total runoff volumes in CT were 2 times greater than that of NT fields with 25-mm rainfall events yet were 4 times greater in CT than NT with 62-mm rainfall events. Results from the total rainfall runoff collection study closely follows the results of the rainfall simulations conducted on the same site and are explained by increased soil content and size of water stable aggregates (Anders et al., 2010) in NT and LD compared with CT. Soil analysis, reported by Anders et al. (2010), showed that soil aggregate content was greater in NT compared with CT, indicating potential for greater soil porosity, improved water infiltration rate, and reduced erosivity of soil. Regarding the factor of storm size, research from western Oklahoma over a 15-yr period showed that storm size was the most important

![Figure 4. Total runoff leaving 2.6-ha wheat fields during 2005 to 2006 crop year by rainfall accumulation per 24-h event.](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Tillage system</th>
<th>No tillage</th>
<th>Light disk</th>
<th>Conventional</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5 cm depth</td>
<td></td>
<td>1.50 by</td>
<td>1.58 by</td>
<td>0.99 ax</td>
<td>0.04</td>
</tr>
<tr>
<td>5 to 10 cm depth</td>
<td></td>
<td>0.78 x</td>
<td>0.84 x</td>
<td>0.92 x</td>
<td>0.04</td>
</tr>
<tr>
<td>Nitrogen, mg/kg</td>
<td></td>
<td>1,749 by</td>
<td>1,725 by</td>
<td>1,155 ax</td>
<td>44.5</td>
</tr>
<tr>
<td>0 to 5 cm depth</td>
<td></td>
<td>997 x</td>
<td>1,000 x</td>
<td>1,083 x</td>
<td>44.5</td>
</tr>
<tr>
<td>5 to 10 cm depth</td>
<td></td>
<td>61 by</td>
<td>65 by</td>
<td>42 ax</td>
<td>3.2</td>
</tr>
<tr>
<td>Phosphorus, mg/kg</td>
<td></td>
<td>43 x</td>
<td>44 x</td>
<td>42 x</td>
<td>3.2</td>
</tr>
<tr>
<td>Calcium, mg/kg</td>
<td></td>
<td>1,598 by</td>
<td>1,738 by</td>
<td>1,262 ax</td>
<td>94.5</td>
</tr>
<tr>
<td>0 to 5 cm depth</td>
<td></td>
<td>1,166 x</td>
<td>1,327 x</td>
<td>1,278 x</td>
<td>94.5</td>
</tr>
<tr>
<td>5 to 10 cm depth</td>
<td></td>
<td>18.9 by</td>
<td>20.4 by</td>
<td>13.9 ax</td>
<td>0.69</td>
</tr>
<tr>
<td>Sulfur, mg/kg</td>
<td></td>
<td>12.7 x</td>
<td>13.0 x</td>
<td>13.5 x</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Table 2. Soil analysis of small grain fields after 8 yr of management using no tillage, light disk and broadcast, or conventional clean tillage methods of establishment

$a,b$ Means within rows with differing superscripts differ ($P < 0.05$).

$x,y$ Means within columns with differing superscripts differ ($P < 0.05$).
factor in determining total runoff from graminoid cover pastures (Wine et al., 2012).

Soil nutrient content was analyzed after 8 yr of continuous management for small-grain pasture using the CT, NT, and LD methods (Table 2). In the top 5 cm of soil, NT and LD contained more ($P \leq 0.02$) soil C, N, P, Ca, and S than CT although there were no differences ($P \geq 0.24$) in these nutrients in the 5- to 10-cm soil horizon. Interestingly, the NT and LD fields had greater content of these nutrients in the 0- to 5-cm horizon than in the 5- to 10-cm horizon, but because of soil mixing with tillage operations the 0- to 5-cm and 5- to 10-cm horizons in CT did not differ in content of these nutrients. Soil content of several of the microminerals tested (B, Na, Mg, Zn, and Cu) followed the same trends. Establishment method did not impact ($P \geq 0.24$) the soil concentration of K, Fe, or Mn.

It has been estimated that up to 60% of soil OM has been depleted with cultivation (USDA, 2003). Soil OM serves to hold water and nutrients, improves soil structure, filters pollutants, and degrades contaminants, thereby decreasing sediment load and nonpoint pollution of streams and waterways. With tillage, soil C can be emitted into atmosphere as CO$_2$ or runoff with soil particulates. These results indicate that increasing the intensity of tillage operations reduces soil structure (Anders et al., 2010) and increases potential for erosion, thus increasing the potential for the movement of soil nutrients into streams via nutrient runoff.

**SUMMARY AND CONCLUSIONS**

As feed costs increase, profit potential and value of gain of forage-based stocker production systems have increased correspondingly. The historic trends that tie the value of BW gain during the stocker segment to the cost of BW gain in the feedlot continue to hold true. Because the beef industry has the opportunity of high value of BW gain, stocker production systems that trade low animal performance for reduced cost of production (unsupplemented warm-season grass or TF) result in increased cost of gain and reduced profitability compared with production systems that may increase capital outlays but result in high animal performance. Production systems can be designed that increase productivity, reduce production and economic risk, and provide benefits to the environment.

**LITERATURE CITED**


