INTEGRATED CROP–LIVESTOCK SYSTEMS TO CONSERVE SOIL AND WATER RESOURCES IN THE SOUTHEASTERN USA

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ABSTRACT

Agricultural production and natural resource conservation need to be balanced to meet the needs of society. To achieve goals of high agricultural production while protecting the environment, modifications to current production systems are needed. Melding new and existing technologies to achieve these two societal goals is possible. Crop rotations with pastures could enhance nutrient cycling, suppress diseases, and help control pests. Ruminant livestock could consume lignocellulosic crop byproducts to add value to farming operations. Animal manures could become more effectively utilized as nutrient sources in farming systems to reduce the cost of fertilizer inputs. Covering the soil with surface residues using conservation tillage and perennial pastures could greatly improve water quality and stop the insidious spoil of soil erosion. By integrating crop and livestock production systems, more farmers will be able to farm the land because of (i) greater stability of income from diverse sources of operations and (ii) greater environmental protection of soil and water resources that will develop from the closer water, nutrient, and energy cycles shared by crop and livestock operations.

INTRODUCTION

The southeastern USA has many contrasting environmental and social characteristics that have often limited the attainment of balanced agricultural production with natural resource conservation. For example, the rich climatic resources (i.e., warm and mild temperatures with abundant precipitation) contrast with the relatively poor condition of soil resources (i.e., low soil organic matter, soil pH, nutrient reserves, and water-holding capacity). Culturally, the region has blossomed and been subsequently admonished from various developments, such as slavery and immigration (European settlers, Latin American laborers, and affluent businessmen). Historically, land was often cleared for farming and subsequently abandoned as productivity declined; early settlers often moving west to more fertile and available land. Even as recently as the 1970s when soybean hit record high prices, woodlands were cleared, and pastures were converted to crop production. With the decline in yield and price soon thereafter, land was converted to Conservation Reserve Program or again abandoned.

Agricultural production and natural resource conservation require continual adaptation of existing technologies with historical knowledge and emerging research and development. Progressive adaptation to socio-economic conditions and political pressures will lead to less stressful changes than abrupt developments caused by tragedy and disaster. The current separation of crop and livestock operations is commonplace throughout the USA, but it is not a natural or sustainable development. Cropping without animals requires extensive external inputs of inorganic fertilizer and pesticides, all based on a finite supply of fossil fuels. Confined animal production requires large inputs of grain, often produced outside of the region, which when processed through animals, becomes an environmental liability, because of concentrated waste disposal. There are many good reasons to re-integrate crop and livestock production systems, both from production and environmental perspectives. However, another immediate reason to develop modern integrated crop–livestock production systems is to capture the experiences of farmers with knowledge of historical conservation practices and meld this information with modern conservation technologies.

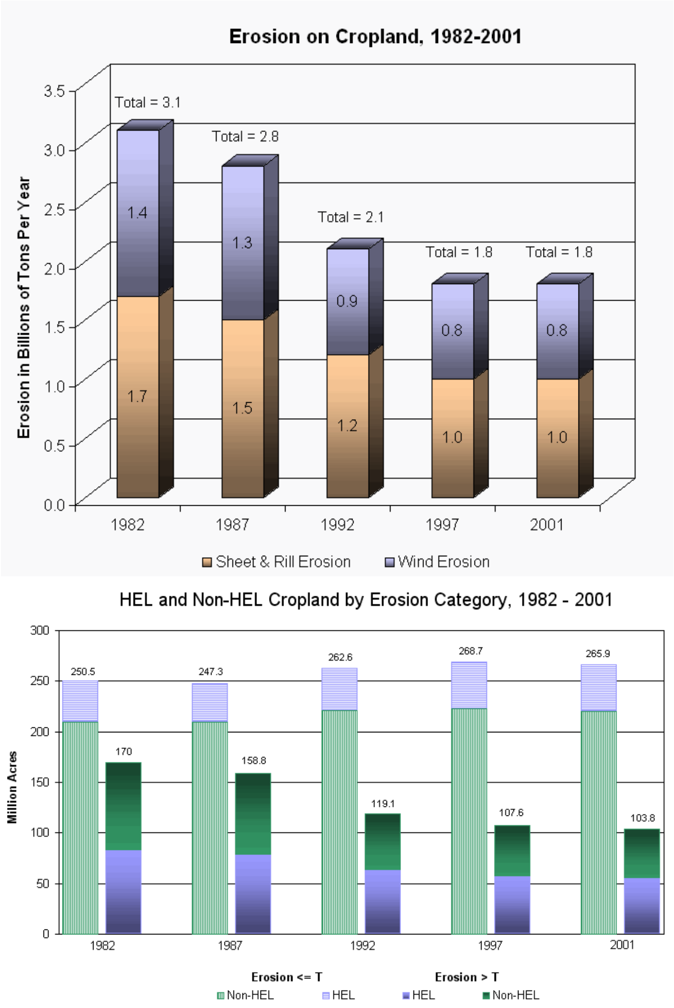

Figure 1. Soil erosion in the USA from 1982 to 2001. HEL is highly erodible land. T is the soil loss tolerance (maximum rate of annual soil erosion) that will permit crop productivity to be sustained economically and indefinitely. From http://www.nrcs.usda.gov/Technical/land/nri01/erosion.pdf.

Soil erosion has been, and continues to be, a major concern of agricultural production throughout the USA and around the world. Although there has been a positive trend in the USA for declining erosion rates during the past few decades (Fig. 1), the fact that 28% of the crop land in the USA may still be experiencing excessive soil erosion (erosion > T) is a cause for immediate concern, requiring remedial action of a nature beyond current approaches. Soil erosion is a disfiguration of the landscape that destroys the long-term integrity of one of our key natural resources that is vital to all of agriculture and society, who depend greatly upon the soil for their food and fiber needs.

One of the most effective management practices for controlling soil erosion is planting of permanent grass cover. Pastures, therefore, can provide environmental protection from soil erosion, as well as be managed for profit with the production of grazing animals. Once sufficient soil cover is achieved with perennial vegetation, soil erosion can be immediately abated even though water runoff may continue until longer term soil physical improvement occurs (Fig. 2). Many investigations have shown the benefit of sod-based cropping systems for controlling soil erosion and water runoff (Hendrickson et al., 1963a, b; Thomas et al., 1967, 1968).

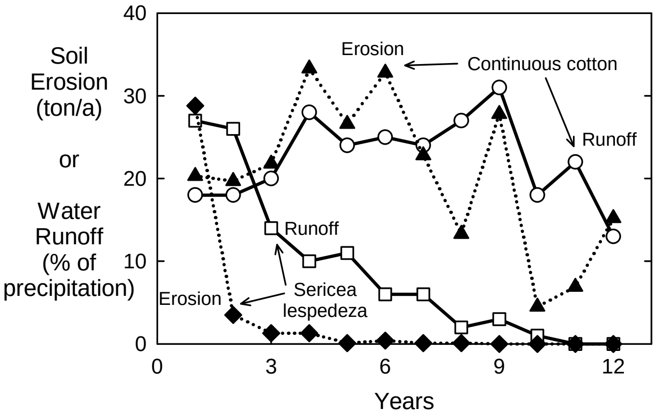

Figure 2. Soil erosion and water runoff from conventionally-tilled continuous cotton and sericea lespedeza planted as permanent cover. Data from Barnett (1965).

Integration of crops and livestock was a common approach to agricultural production throughout the southeastern USA prior to World War II. Technological advances in plant genetics, machinery, and synthetic chemicals improved agricultural production many-fold, and eventually shifted diverse agricultural enterprises into specialized production facilities. Today, agriculture is faced with challenges and opportunities, not necessarily unique from the past, but melded with a diverse range of societal and ecological concerns about how the world and its people can be sustained. A growing awareness is emerging that the stability and resiliency of agricultural landscapes appear to be impaired by enterprise specialization, concentration of operations, and expansion of scale, which have spatially and temporally compartmentalized and disrupted energy and nutrient cycles in a manner far removed from natural ecosystem cycling (Gates, 2003). Returning agricultural systems to more integrated crop and livestock production has the potential to greatly improve the environment and to support sustainable agricultural production by:

- Reducing soil erosion
- More efficiently utilizing natural resources
- Exploiting natural pest control processes
- Reducing nutrient concentration and consequent environmental risk
- Improving soil structure and productivity

Ruminant livestock should be considered an important part of an integrated approach, because they can convert cellulosic feedstuffs from traditional pastures and crop residues into high-value meat and milk products (Oltjen and Beckett, 1996). Pastures grazed by ruminant livestock can be an effective management option to reduce soil erosion (Hendrickson et al., 1963b; Harden et al., 1999).

Our aim in this paper was to outline some specific integrated crop–livestock production scenarios that comprise viable options to conserve soil and water resources for agricultural producers throughout the southeastern USA, while simultaneously reducing the cost of production and/or increasing productivity.

INTEGRATED CROP-LIVESTOCK PRODUCTION SCENARIOS

Rotation of Long-Term Pastures with Crops

Although considered a historical practice, rotation of pastures with crops has the potential to provide many agronomic, environmental, and economic advantages. The development of herbicide-tolerant crop varieties and improved machinery for conservation-tillage production systems has created new opportunities for producers to make a profit, in addition to protecting the environment, when employing sod-based agricultural production strategies.

Accumulation of soil organic matter often occurs at a high rate under pastures as a result of the perennial vegetation and high input of organic materials from animal feces, ungrazed forage, and roots (Franzluebbers et al., 2000). Much of the accumulation of soil organic matter in the southeastern USA is near the soil surface (Fig. 3), a zone in which weather causes maximum variation in soil thermal and hydraulic properties to help preserve it, but also a zone that helps mitigate compaction and allows for high water infiltration (Fig. 4). Many studies have shown the positive benefits of greater soil organic C on various other soil chemical, physical, and biological properties, which can promote greater crop production (Studdert et al., 1997; Diaz-Zorita et al., 2002; Garcia-Prechac et al., 2004). Annual crops planted after long-term pastures benefit from the slow release of nutrients sequestered in soil organic matter (Giddens et al., 1971). On farmers' fields in Argentina, wheat grain yield was positively related to soil organic C (Diaz-Zorita et al., 1999). In addition, no-tillage planting in sod preserves the macropores necessary for high water infiltration in non-cracking soils, while retaining cover to minimize soil erosion.

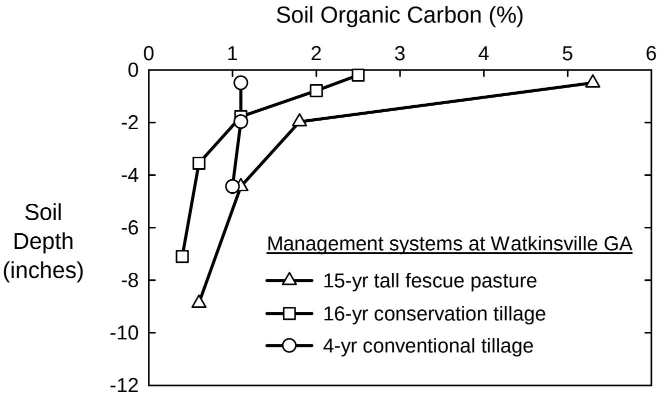

Figure 3. Soil organic C depth distribution as affected by long-term management on Cecil sandy loam in Georgia.

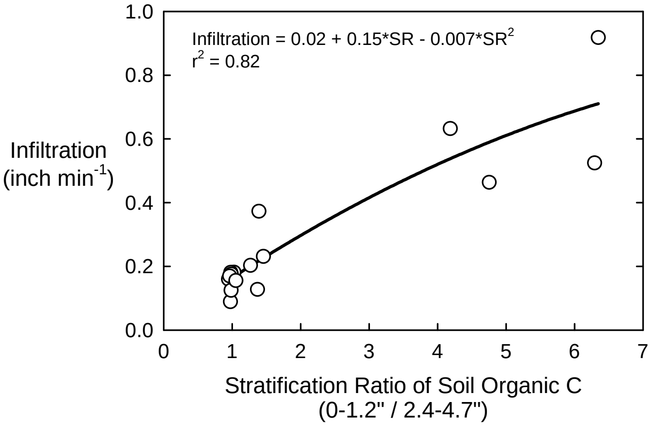

Figure 4. Water infiltration rate as affected by the stratification ratio of soil organic C in a Cecil sandy loam in Georgia (Franzluebbers, 2002).

As one example, the following protocol is suggested for cropping following warm-season perennial sod, either managed as grazed pasture or as Conservation Reserve Program land:

✓ Plant Roundup-Ready corn or soybean varieties in spring, with planting date based on latitude. Apply Paraquat or glyphosate to control existing vegetation (paraquat defoliates plants rapidly and conserves soil moisture). This will destroy cool-season vegetation. The presence of some persistent broadleaf weeds may require a mixture of 2,4-D or dicamba with glyphosate as a pre-plant herbicide application. Fields should be scouted to determine the best herbicide and timing. After the crop has emerged and warm-season perennial vegetation has begun to green up (e.g., 3 to 4 weeks after planting), apply glyphosate over the top. If annual grasses and broadleaf weeds are anticipated as a problem, add atrazine or other herbicide with second glyphosate application. Competition from the vigorously developing corn or soybean crop will suppress most subsequent weed growth. Soil test and apply lime and nutrients, as needed. Apply N as broadcasted ammonium nitrate or knife in other forms of N. Broiler litter adds nutrients and mulch cover. The C factor for the USLE should range from 0.01 to 0.001 for this management strategy, which will permit cropping of many upland sites without creating an unacceptable erosion hazard. With erosion minimized using good management on upland sites (corn yield of 120-150 bu acre^{-1}), perhaps it is time to rethink our definition of marginal land. With mulch cover, water is conserved from reduced evaporation and increased infiltration, especially on soils that do not crack and rely on macropores for infiltration. Corn can either be harvested for grain or grazed by steers. Grazing would add value to both the animals and crop. Also, harvest by grazing would not require the producer to own a combine or arrange for custom harvest. Large steers (800-900 lb head^{-1}) stocked at 1.5-2 head acre^{-1} have gained 2 lb day^{-1} with 90% of animals grading at choice or select. Animals can be introduced at the R3 stage of corn and allowed to creep-graze 5-10% of the crop area, starting at a water source. As corn is consumed, the fence is moved so that feed is never limiting. Crops could be rotated in subsequent years, so that herbicides can be changed to control problem weeds. Harvest by cattle grazing attracts wildlife species, which could also become an additional source of income from fee hunting. Doves are especially attracted to this management strategy. Whether this practice could be worked into a Wildlife Habitat Enhancement Program should be investigated.

Potential benefits of conservation-tillage planting of corn or soybean into pastures could be:

- Elimination of wild forms of endophyte-infected tall fescue, which can reduce animal performance and production (Stuedemann and Hoveland, 1988). Replacement of wild-endophyte-infected tall fescue pastures with non-toxic tall fescue-endophyte associations can cost an estimated \$200 acre^{-1} (David Lang, personal communication), or even up to \$500 acre^{-1} (Zhuang et al., 2005). By growing corn or soybean, herbicide costs can be embedded in the cost of crop production, while obtaining a marketable commodity. Renovation cost could be cut in half with a short-term crop rotation. Cool-season crops can be drilled into the pasture while still occupied by grazing animals.
- Control of problem weeds in pastures. A smutgrass problem in a pasture in southern Mississippi was reduced 90% following grazed, no-tillage corn with two applications of glyphosate (David St. Louis, personal communication). Bermudagrass survived following this treatment. As this management system develops, other weed problems may appear. Typically however, periodic rotation with an annual crop could reduce cost and generate income. Currently, control of smutgrass requires an expensive herbicide (Velpar) and about 2 months with no grazing.
- Greater income potential from upland sites. Cow-calf systems typically return \$15-25 acre^{-1} year^{-1}. Grazing steers on corn has the potential to increase this return. Group IV and V, non-irrigated soybean has consistently yielded $\geq$50 bu acre^{-1} in upland variety trials in Mississippi (2005 MS Soybean Variety Trials, Information Bulletin 425, MAFES). Whether this yield can be achieved with conservation tillage on upland sites is not known, but if possible, then profit should be high (\$300 acre^{-1} gross return with \$130 acre^{-1} input cost).
- Greater labor efficiency. Crop production is characterized by periods of intense activity with other times of no activity. For example, corn and soybean have an optimum planting period lasting 3 to 4 weeks. Harvest season is about the same length. Planting and spraying for crop establishment are rapid, low draft operations. Frequent spring rains limit field time,

because wet soil limits tractor traffic. However, untilled soil supports traffic much better than tilled soil, thereby increasing field operation potential. By using no-tillage management, the number of trips can be reduced and acres covered by a laborer can be increased (Triplett et al., 2002). Partial budgeting practiced by economists does not usually address this issue.

Short-Term Grazing of Cover Crops

Cover crops provide a viable short-rotation opportunity for almost any cropping sequence in the southeastern USA. Although most previous research has been with ungrazed cover crops, adding a cover crop component can improve productivity potential and reduce environmental threats from erosion (Langdale et al., 1991) and nutrient loss (Meisinger et al., 1991; Sharpley and Smith, 1991). Despite extensive research conducted with cover crops (Hargrove, 1991; Sustainable Agriculture Network, 1998), and increasingly in combination with conservation tillage systems during the past two decades, there remains a paucity of information on how cover crops have been successfully integrated into crop–livestock systems.

Benefits from cover crops in cropping systems are numerous, including:

- controlling soil erosion
- reducing water and nutrient runoff
- improving soil tilth, structure, water infiltration, and nutrient cycling
- modifying soil moisture, by increasing uptake and reducing evaporation at different times of the year. In the southeastern USA, the soil profile will almost always by fully recharged over winter, but moisture use and delayed planting of warm season crops to achieve greater cover crop growth in spring (as well as greater N fixation by legumes) should be considered.
- contributing to soil organic C sequestration and soil biological diversity
- controlling weeds through competition, allelopathy, and microclimatic alteration
- controlling insect and disease pressures ecologically
- serving as a nutrient trap in high-fertility systems
- if leguminous, providing biologically fixed N to the cropping system

As summarized by Gardner and Faulkner (1991), having ruminant livestock utilize cover crops in a crop production system could increase the value of cover crops, because “planting and caring for a crop that apparently serves no immediate economic and harvestable purpose is both a foreign and unknown practice in much of the world . . . details, time, and skill required to manage both crops and livestock are obvious adoption barriers to seeing cover crops as pasture”. They also stated that the most basic barrier to adoption of integrated crop–livestock systems today is that many producers are reluctant to obtain or manage grazing livestock, because of a lack of experience and/or time during critical crop management periods. Livestock increased labor required on an average North Dakota farm by 56%, but only ⅓ of the additional time competed directly during critical crop management (Gardner and Faulkner, 1991).

Adams (1950) wrote “There is no substitute for good rotations in a diversified agriculture. By establishing good stands of close-growing legumes on the land, an excellent base for crop rotations is provided.” Vetch as a cover crop for continuous corn production can supply enough N that corn grain yield would not respond to additional N fertilizer (Fig. 5). With N fertilizer price rising to $\geq$\$0.50 lb^{-1} N, the cost of seeding a legume cover crop to obtain biologically fixed

N has become much more competitive than in previous decades (e.g., seed and application costs of crimson clover and other legumes would be approximately \$20-40 acre^{-1} compared with \$50 acre^{-1} with the application of 100 lb N acre^{-1}). The recent development of glyphosate-tolerant alfalfa promises to improve forage production and N fixation for subsequent crops in rotation. On suitable, well-drained sites, extending the life of alfalfa by one or two years will spread the cost of establishment over a longer period. A $\geq$2-year stand of alfalfa can be killed with herbicide and furnish enough N for 150 bu acre^{-1} of corn (Triplett et al., 1979).

A fully replicated field experiment investigating crop, animal, and soil responses to three management factors was initiated in 2002 near Watkinsville GA. Land previously in 20 yr of grazed tall fescue paddocks was converted to two cropping systems (sorghum grain + rye cover crop or wheat grain + pearl millet cover crop) managed under two tillage systems (no tillage or conventional with initial moldboard plow followed by disk tillage) and two cover crop scenarios (cover crop left ungrazed or grazed by cattle). During the first 2 years of production, sorghum and wheat grain yields were unaffected whether cattle were allowed to graze cover crops or not (Franzluebbers and Stuedemann, 2005a). Cover crops were more productive under no tillage than under conventional tillage (Fig. 6). Because of the greater productivity of cover crops, both cattle performance and total gain on paddocks were also greater under no tillage than under conventional tillage. From an agronomic perspective, cattle grazing of cover crops did not harm crop production. The integration of livestock with crops improved production from a whole-farm

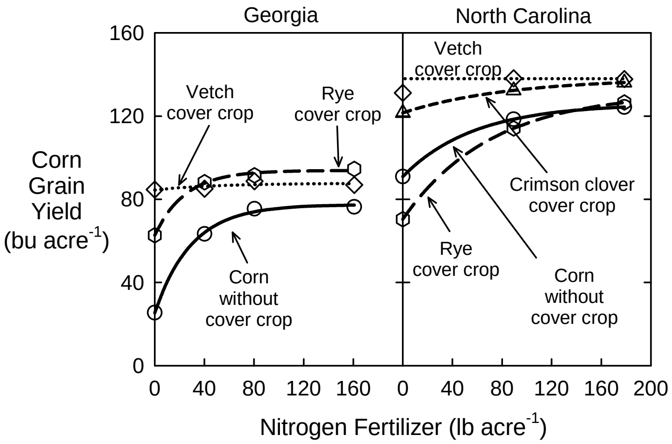

Figure 5. Corn grain yield response to N fertilizer application as affected by winter management. Georgia data from 1958 to 1964 near Watkinsville (Adams et al., 1970a). North Carolina data from 1984 (McLeansville) and 1985 (Reidsville) (Wagger, 1989).

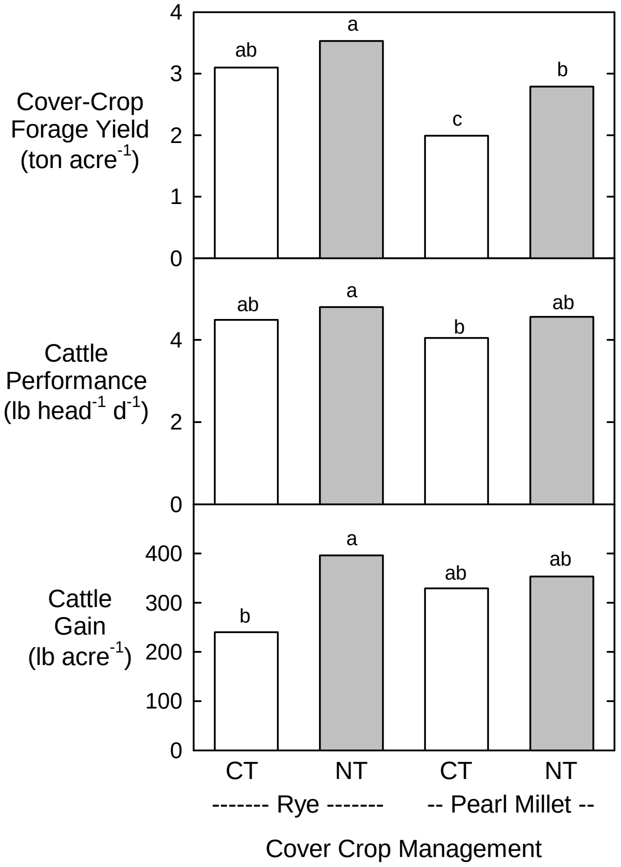

Figure 6. Cover crop forage mass production, calf performance, and cow/calf weight gain as affected by cover crop type and tillage management (CT is conventional tillage and NT is no tillage) averaged across two years. Data from Franzluebbers and Stuedemann (2005a).

perspective by utilizing cover crop biomass as a forage for cattle production. Producing crops with conservation tillage was superior to that with conventional tillage.

The effect of grazing cattle on soil properties was variable. Soil penetration resistance tended to be higher under grazed than ungrazed condition, but values depended largely upon antecedent soil water content at the time of measurement (Franzluebbers and Stuedemann, 2005b). Soil organic C concentration was initially highly stratified with depth and remained so with no tillage, but became uniform with depth following termination of perennial pasture with moldboard plowing. A change in soil organic C due to the presence of grazing cattle was not evident. Initial soil responses to grazing appear to be minimal, suggesting that the greater economic return and diversity by grazing of cover crops could benefit production and economics without damage of the environment. This research needs to be continued for validation of these implications.

Relay or Inter Cropping

Planting of annual crops into long-term pasture has been investigated in the past (Welch et al., 1967; Adams et al., 1970b; Carreker et al., 1973; Box et al., 1980; Harper et al., 1980; Wilkinson et al., 1987). These studies have included winter small grains drilled into bermudagrass, as well as corn planted into partially or completely killed tall fescue sod. Goals of such systems were to obtain simultaneous benefits from a number of opportunities within such a system:

- elevate agroecosystem productivity to match the region's climatic potential
- control erosion without full-width tillage by sowing into well-established sods that have proven erosion control effectiveness
- invigorate a pasture by disturbing the sod, but obtaining a harvestable yield component
- create a heavy nutrient demand for application of disposal rates of broiler litter
- harvest the ephemeral benefits of rotation from soil physical (aggregation, water retention), chemical (N mineralization, cation availability), and biological (disease suppression, microbial activity) improvements

Modern pasture-crop intercropping systems could also be developed with success, because of the new technologies that would allow more effective weed control and precision planting and harvesting.

In Mississippi, annual ryegrass for winter grazing is grazed out and land stays idle during summer. By relay intercropping, corn for grazing could be established while utilizing the ryegrass. Winter grazing could be re-established while grazing the corn. Wheat would be a good winter grazing crop prior to corn, because peak biomass production would occur earlier to accommodate early corn planting.

Agroforestry

Most agroforestry systems involve grazing perennial forages. With wide tree spacing, annual crops such as corn or soybean can be grown during the time when trees are too small for grazing animals to be present. Grain harvest would generate income on the front end of the tree stand. In Mississippi, corn has been grazed by cattle in such a system, rather than harvesting by machine. During initial research, accelerated tree growth from fertilizer applied to corn has been observed, which would shorten the tree rotation. This management system improves potential for weed control in the tree stand with ground equipment and herbicide selection. With wide alleys between twin rows of trees, limbs have to be pruned next to the open area. With increasing maturity of trees and as annual crops become shaded, planting of perennial forages would become better suited as an understory.

SUMMARY AND CONCLUSIONS

Conservation of soil and water resources is a necessity in our world of ever-changing and competing human activities. Meeting the food and fiber demands of a growing world population will only become more difficult with competing energy and natural resource commitments. Integration of crops and livestock has great potential to improve resource efficiency of agricultural production in the southeastern USA and around the world. A few examples of how this can be accomplished were presented, but much more research is needed to optimize systems within the unique circumstances of local and regional conditions.

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