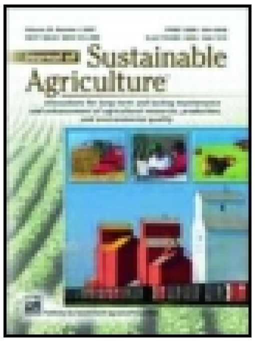

Journal of Sustainable Agriculture

ISSN: 1044-0046 (Print) 1540-7578 (Online) Journal homepage: http://www.tandfonline.com/loi/wjsa20

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Journal of Sustainable Agriculture, 34:532–548, 2010

ISSN: 1044-0046 print/1540-7578 online
DOI: 10.1080/10440046.2010.484697

Labor Availability in an Integrated Agricultural System

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The trend towards crop specialization and increased farm size in U.S. agricultural systems has had negative economic and environmental impacts. On large, specialized farms, bottlenecks in labor occur, and a significant amount of seasonal labor is underutilized. This study was conducted to determine if this labor could be allocated to the production of supplemental enterprises. A linear programming analysis confirmed that 2,807 hours of underutilized labor exists in a typical corn-soybean rotation and that integration of the supplemental crops evaluated in our study are feasible. Grazing of stalk residues alone did not make use of the underutilized labor, however, integration of two alternative cabbage production scenarios as well as an agroforestry alternative that included decorative woody florals made use of an additional 357 and 306 hours of the underutilized labor, respectively. The integration of supplemental alternative crops into an existing corn–soybean rotation has the ability to make use of underutilized labor and has potential to increase farm profitability and improve agronomic and environmental sustainability.

We gratefully acknowledge the Cooperative States Research, Education, and Extension Service and the McIntire Stennis Forestry Research Program for their financial support of this research.

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KEYWORDS corn-soybeans, livestock, cabbage, windbreaks, woody florals, integration, sustainability, labor

INTRODUCTION

Historically, Midwestern U.S. farming units were highly diversified, with families managing a wide variety of crops and livestock that were integrated across the whole farm. During the 20th century, the production efficiency of commodity crops like corn (*Zea mays L.*) and soybean [*Glycine max (L.) Merr.*] was greatly increased through mechanization and the widespread availability of relatively cheap chemical fertilizer and pesticide inputs (Egli, 2008). As a result, many Midwestern farmers specialized, and mixed crop and livestock farming systems were replaced by the intensive production of one or two grain crops (Medley et al., 1995; Sulc and Tracy, 2007). Over time, however, the relative value of these commodity crops declined and many producers increased farm size to maximize 'economies of scale.' By taking advantage of the efficiency of larger farm equipment and new agricultural chemicals they reduced input costs/unit produced (Karlen et al., 1994; Dimitri et al., 2005). Average farm size increased substantially since 1980, and 'large' and 'very large' farms now account for the majority of agricultural production (Paul and Nehring, 2005).

Consequently, while farm labor was more fully utilized on traditional diversified farms prior to WWII (Sulc and Tracy, 2007), large, specialized farming systems often experience bottlenecks in farm labor, due to high labor demands during a few weeks in the spring and fall, and underutilized labor throughout the rest of the year. A study in Oklahoma of a typical cow-calf and grain farming operation found that, of the 2,500 hours of operator labor available on a typical farm, only 675 hours (27%) were utilized for the production of these standard farm enterprises (Schatzer et al., 1986). In an effort to supplement their income, many farmers resort to off-farm employment during periods of underutilized labor in the summer and winter. Nationally, about 55% of farm operators and nearly 50% of farm operator spouses now hold off-farm jobs (Offutt, 2002). Alternatively, farm producers could enhance their agronomic, economic and environmental sustainability by utilizing these periods of underutilized labor for production of supplemental crop enterprises (Dagliotti et al., 2005; Cittadini et al., 2008).

The extensive use of simple, short-term rotations with limited diversity has led to reliance on the use of off-farm inputs to maintain production efficiency, and resulted in a number of negative environmental impacts (Sulc and Tracy (2007). For example, the growing hypoxic zone in the Gulf of Mexico has been linked to the extensive use of nitrogen fertilizer in intensive Midwestern U.S. agricultural systems (Burkart and James, 1999). Alternatively, the conversion of these systems to low-input management strategies based on crop diversification and livestock integration can result in a series of synergisms and complementarities among farming system components, leading to more balanced nutrient and pest management cycles (Altieri and Rosset, 1996). For instance, the integration of livestock in a cash grain operation has the potential to enhance soil fertility by accelerating nutrient cycling and reducing the need for nitrogen fertilizer inputs (Russelle et al., 2007). In well designed systems, interactions among the integrated enterprises and components should enhance biological synergisms and result in increased production efficiency and economic viability (Parker, 1990).

The feasibility of integrating supplemental crops into an existing crop rotation has been explored using computer simulation models (Rossing et al., 1997; Olson, 1998; Messele et al., 2001; Dagliotti et al., 2005; Cittadini et al., 2008). For example, Olson (1998) found that smaller farms could increase net income per acre and remain competitive with larger farms by adding high-value crops to their standard corn-soybean rotation. This occurred not only because of the increase in income from the sale of these supplemental crops, but also as a result of increasing on-farm biodiversity and the potential reduction in overall input costs resulting from biological synergisms. Yet few studies have specifically investigated the labor requirement of U.S. Midwestern grain farms and labor availability within an integrated farm system. In one example, Schatzer et al. (1986) demonstrated the feasibility of integrating various vegetable crops into an existing farming operation based on the underutilized labor available in a traditional row-crop operation. The labor requirements for broccoli (*Brassica oleracea* L. var. *italica* Plenck.) production occurred primarily in the early spring and summer months during an off time for traditional farm enterprises.

Our research was undertaken to determine the feasibility of integrating various supplemental enterprises into a traditional corn–soybean production system and more fully use the available farm labor throughout the year. The objective was to identify supplemental cropping alternatives that are agronomically feasible, would contribute to economic and environmental sustainability of the operation, and would not require substantial additional specialized machinery or knowledge by the producer. The four farm options considered were: 1) a base farm with a 256 hectare corn-soybean rotation; 2) the base farm plus corn stalk grazing by cattle (*Bos taurus* L.); 3) the base farm plus either winter wheat (*Triticum aestivum*) followed by fall-planted cabbage (*Brassica oleracea* L. var. *capitata* L.) or spring-planted cabbage followed by oilseed sunflowers (*Helianthus anuus* L.); 4) the base farm protected by shelterbelts that included woody species selected for production of decorative floral stems, referred to henceforth as the agroforestry alternative.

MATERIALS AND METHODS

To evaluate the feasibility of integrating supplemental crops into an existing corn–soybean rotation, the labor availability and detailed labor schedules for a typical model 'base farm' and each of the supplemental enterprises were developed. A linear programming (LP) model was established to evaluate the various alternatives and to determine the optimal hectare allocation to the various farm enterprises.

Base Farm

The base farm in our analysis was designed to represent a typical family sized Midwestern U.S. farming operation. It was 256 ha is size, and located in eastern Nebraska growing dryland corn and soybean for grain in rotation, with half of the farm planted to each of these crops in any given year (Bernhardt et al., 1996). Most of the equipment was owned and chemical applications were based on standard recommendations (Olson, 1998; Bernhardt et al., 1996). Site conditions were based on the University of Nebraska-Agricultural Research and Development Center (UNL-ARDC) Agroforestry Farm in Saunders County near Mead, Nebraska (longitude W96o 29′, latitude N41o 14′).

Eastern Nebraska lies within the western Cornbelt ecoregion (Omernik, 1987). Terrain is flat to rolling and has glaciated soils will a loess mantel overlay. The continental climate has annual precipitation of 635 mm to 812 mm which is highly variable from year to year, with maximum rains in spring and early summer (Olson, 1998). Average (10 year) minimum and maximum temperatures (Celsius) by month during the growing season are: April—3.4 & 17.2; May—9.8 & 23.0; June—15.2 & 28.7; July—17.8 & 36.4; August—16.3 & 29.6; September—11.1 & 25.4; October—4.0 & 18.7. The typical frost-free season is between 145 and 175 days (HPCC, 2003). Nitrogen is usually the most limiting soil nutrient and anhydrous ammonia is the most common fertilizer practice for corn in the area. Crops are generally sold directly to the elevator at the time of harvest for market price.

Labor Availability

The availability for both field and non-field time of one full-time operator was determined. Field time availability indicates the time needed for farm production tasks such as tillage, planting, spraying, and harvest. Because there are many farm tasks such as equipment repair, bookkeeping, input purchases and marketing that do not necessarily need to occur during field time, a non-field labor availability category was also established.

Annual records of the number of field days suitable for field operations throughout the growing season were available from the Nebraska

Agricultural Statistics Service (NASS, 1991–2002). This assessment was based on temperature and soil moisture conditions as influenced by rainfall, wind velocity, and relative humidity. The number of days suitable for fieldwork was determined for Saunders County and an 11-year average (1991–2001) was calculated on a weekly basis.

The number of daylight hours per day, based on sunrise and sunset for Mead, Nebraska, was determined in order to calculate the hours per week the producer could expect to be available for each work category (U.S. Naval Observatory, 2002). Farm producers often work into twilight hours or use lights on their equipment to gain more flexibility during critical times; however this was not included in the present analysis.

It was assumed that a typical producer would work, at the most, 6 days per week during critical time periods, allowing at least one day off for holidays or personal activities. The number of daylight hours was used as a per day limit. The number of days available each week for field activities was subtracted from the total days per week to establish the days available for non-field activities.

The LP model was programmed so that the unused labor in each time period allocated to available fieldwork could be transferred to the non-field time availability category if needed. For example, while the harvest of woody florals occurs outside during daylight hours, it does not require a specific temperature or available soil moisture and can therefore be performed during available non-field time. However, non-field time could not be transferred to field time as this was based on important temperature and field characteristics. For example, during these times it might be too wet to operate farm equipment in the field.

Labor needs for the base model farm were derived from Olson (1998) and modified using input from the UNL Agroforestry Farm operating records. Typical tasks, duration of each task based on available equipment and the dates needed were determined. The tasks were separated into those requiring field time and those that could occur at other times, or "non-critical" tasks (Table 1).

While the complete reintroduction of livestock into the grain production operation is advisable given possible production synergies, it was not included in the analysis. This analysis focused only on grazing of stalk residues by cattle from a neighboring livestock owner. This option required no additional labor by the cropland owner as the livestock owner provided all required labor, fencing, and other items specific to the cattle operation.

Because cabbage is a cool-season crop requiring only 85 days from transplanting to harvest and is best grown at the beginning or end of the growing season when temperatures are cooler, two possible variations in crop rotations were considered: 1) winter wheat followed by fall cabbage, and 2) spring cabbage followed by sunflower. The tasks to produce one

TABLE 1 Tasks and Labor Schedule for the Production of the Base 256-ha Corn–Soybean Farm Enterprise

Field tasks	Hectares	Hours	Date	Non-field tasks	Hours	Date
(During growing season)				(Winter off-time – 25 weeks)		1/1–4/1 & 10/8–12/31
Disc corn ground	128	41	4/9–4/15	Maintenance & Repair	94.6	
Disc soybean ground	128	41	4/16–4/22	Bin Unloading & Cleanout	16	
Apply fertilizer	128	33	4/23–4/29	Planning	40	
Field cultivation	256	47.1	4/23–4/29	Shop Work	40	
Plant corn	128	49.2	4/30–5/6	Building Maintenance & Repair	40	
Spray corn	128	31.4	4/30–5/6	Total Hours	230.6	(9.22 hrs/wk)
Plant soybean	128	49.2	5/14–5/20			
Spray soybean	128	31.4	5/14–5/20	(During growing season – 27 weeks)		4/9–10/7
Cultivate turn rows	24	3	6/11–6/17	Maintenance & Repair	40	
Cultivate soybean	128	47.1	6/25–7/1	Mowing	80	
Rogue soybean	128	Custom	7/30–8/5	Building Maintenance & Repair	40	
Combine corn	128	62.8	9/17–9/23	Shop Work	40	
Combine soybean	128	36.8	10/1–10/7	Planning	40	
Total Hours		472.9		Total Hours	240	(8.89 hrs/wk)
				Total Annual Labor Requirement		943.5

hectare of cabbage were taken from an enterprise budget for integrated crop management developed by Brumfield and Brennan (1996). These data were adapted to include specific duration and time intervals needed for production based on local conditions and experience (Tables 2 and 3). The tasks involved with winter wheat and oilseed sunflower production were obtained from the UNL Agroforestry Farm operating records. The model assumed that cabbage would not require storage, and would be sold directly to minimally processed salad plants.

The agroforestry alternative included a windbreak system consisting of two rows of eastern red cedar (ERC) (*Juniperus virginana L.*). Three windbreaks, 6 m wide and 1530 m long, were established on the north, west, and south boundaries of the farm. A fourth windbreak was established in an east-west direction midway between the north and south windbreaks. The woody floral plots were planted on the southern sides of all three east-west windbreaks. Three species of decorative woody florals with commercial success in eastern Nebraska were included in the model: 1) Scarlet Curls Willow (*Salix matsudana tortuoso* (G. Koidz.) x Scarlet Curls also known as *Salix* x Scarcuzam cv Scarlet Curls) 2) French Pussy Willow or Goat Willow

TABLE 2 Tasks and Labor Schedule for the Production of 1 ha of Winter Wheat/Fall Cabbage

Field tasks	Hours	Date
(During growing season)		
Wheat starter fertilizer	0.2	3/26–4/1
Spray wheat	0.3	5/21–5/27
Harvest wheat	0.4	7/2–7/8
Fertilize cabbage	0.2	7/9–7/15
Disk cabbage & apply herbicide	0.7	7/9–7/15
Cultivate cabbage	0.2	7/16–7/22
Plant cabbage (+ 20 hrs hired labor)	10.0	7/16–7/22
Set up irrigation	10.0	7/23–7/29
Irrigation (7 weeks)	61.3	7/23–9/9
Cultivate cabb. For weed control	0.2	8/13–8/19
Cabbage pest control (4 weeks)	1.0	8/13–9/9
Harvest cabbage	25.0	9/10–9/16
Plant wheat	0.2	10/8–10/15
Total Hours	109.5	(20 hrs hired labor)
Non-field Tasks		
(Winter off-time – 25 weeks)		1/1–4/1 & 10/8–12/31
Marketing	25.0	
Same misc tasks as c-s	0.9	
Total Hours	25.9	(1.036 hrs/wk)
(During growing season – 27 weeks)		4/9–10/7
Same misc tasks as c-s	0.9	
Total Hours	0.9	(0.035 hrs/wk)
Total Annual Labor Requirement	136.3	(20 hrs hired labor)

(*Salix caprea* L.), and 3) Bailey Redtwig Dogwood (*Cornus sericea* L. cv Bailey).

Because the initial time requirements for site preparation and planting for the agroforestry system are relatively high and occur during the same time for planting corn and soybean, the model assumed that a local tree planting company or agency would perform these tasks. The tasks and labor requirements associated with the production of the woody floral crops were taken from a study performed by Josiah (personnel communication, 2002) at the UNL Agroforestry Farm (Table 4).

Linear Programming Model

The labor constraints of this characteristic farm producer along with the labor schedules, and costs and returns for the typical base farm and each of the alternatives were entered into a Linear Programming (LP) model (Hoagland et al., 2009). This mathematical procedure searches for a combination of activities that maximizes a specified value, such as total profit, subject to certain constraints, such as labor availability. It was used to determine the optimal crop mix in each year given the various constraints and alternative crops available to the producer.

TABLE 3 Tasks and Labor Schedule for the Production of 1 ha of Spring Cabbage/Sunflower

Field tasks	Hours	Date
(During growing season)		
Disk cabbage & apply herbicide	0.7	3/19–3/25
Fertilize cabbage	0.2	3/19–3/25
Cultivate cabbage	0.2	3/26–4/1
Plant cabbage (+ 20 hrs hired labor)	10.0	3/26–4/1
Set up irrigation	10.0	4/2–4/8
Irrigation (7 weeks)	61.3	4/2–5/13
Cabbage pest control (4 weeks)	0.5	5/7–5/20
Harvest cabbage	25.0	5/21–5/27
Disk sunflower	0.3	5/28–6/3
Fertilize sunflower	0.2	5/28–6/3
Spray pre-emergent herbicides	0.3	6/4–6/10
Plant sunflower	0.4	6/4–6/10
Cultivate (depends)	0.4	7/2–7/8
Combine sunflower	0.3	10/1–10/7
Total Hours	109.6	(20 hrs hired labor)
Non-field Tasks		
(Winter off-time – 25 weeks)		1/1–4/1 & 10/8–12/31
Marketing	25.0	
Same misc tasks as c-s	0.9	
Total Hours	25.9	(1.036 hrs/wk)
(During growing season – 27 weeks)		4/9–10/7
Same misc tasks as c-s	0.9	
Total Hours	0.9	(0.035 hrs./wk)
Total Annual Labor Requirement	136.4	(20 hrs hired labor)

For each of the four alternatives, the required labor, costs, and returns of each cropping option were established on a per-hectare basis. Because corn and soybean are grown in rotation over a 2-year period, their respective costs and returns were averaged into single values to represent this 1 ha being half corn and half soybean. The winter wheat-fall cabbage and spring cabbage-sunflower options have both crops grown on the same hectare in 1 year, thus their respective costs and returns were summed to determine singular values for the LP model.

Since the model only considered the first six years of production, the agroforestry option was calculated differently. Within our time frame, the LP program could not consider the long-term economic benefits of increased crop yields due to wind protection from the windbreak. Therefore, the model was programmed to accept the 3.74 ha of the windbreak system and subtract these hectares from those to be optimized and allocated to the various alternatives. However, production of the three woody floral crops were still optimized and allocated by the LP program.

To allow the LP model to determine the optimal solution considering all variables over time, a six-year average of the various alternatives was established. For example, production of the woody floral cultivars has high

TABLE 4 Tasks and Labor Schedule for the Establishment and Production of a 3.74 ha Protective Shelterbelt Incorporating Three 150 m Woody Decorative Floral Plots

Field tasks	Date	Yr 1-hours	Yr 2-hours	Yr 3-hours	Yr 4-hours
(During growing season)					
Grade, bundle & delivery	1/8–1/14			2.1	5.0
Harvest & ready for tomorrow	1/15–1/21			0.4	0.9
Grade	1/22–1/28			0.3	0.7
Harvest & grade	1/29–2/4			1.1	2.7
Grade, bundle & delivery	2/5–2/11			2.7	6.5
Harvest	2/19–2/25			0.3	0.7
Grade & bundle	2/26–3/4			0.1	0.3
Grade	3/12–3/18			0.4	1.0
Site preparation	5/21–5/27	4.7			
Plant	5/21–5/27	Custom			
Replant & spray	5/21–5/27		Custom		
Set up irrigation	5/28–6/3	0.7			
Irrigate	6/4–9/23	6.1			
Harvest, grade & delivery	11/12–11/18		4.6	10.9	10.9
Cut, grade & delivery	11/19–11/25		1.8	4.3	4.3
Grade, cut & bundled	11/26–12/2		8.6	20.5	20.5
Cut, grade & delivery	12/10–12/16		1.5	3.5	3.5
Grade & bundle	12/17–12/23		1.5	3.2	3.2
Total Hours		11.5	18.0	50.0	60.3
Non-field Tasks					
(Winter off-time – 25 weeks)	1/1–4/1 & 10/8–12/31				
Marketing		9.0	9.0	15.0	15.0
Miscellaneous		3.4	3.4	3.4	3.4
Total Hours		12.4	12.4	18.4	18.4
(During growing season – 27 weeks)	4/9–10/7				
Miscellaneous		3.6	3.6	3.6	3.6
Total Hours		3.6	3.6	3.6	3.6
Total Annual Labor Requirement		27.5	34.1	72.0	82.3

initial costs and no returns during the first year, but can achieve high returns in successive years. Available capital was regarded as unlimited and was not used as a limiting factor in this analysis. The fixed costs per hectare, including costs such as land and machinery, were held constant for each alternative. Land was held constant at 256 ha for the four alternatives.

The initial LP model focused on the labor constraints of one full-time, farm producer. However, because the availability of labor can be a major constraining factor in the production of high value supplemental crops like the woody florals, the availability of additional labor was considered in subsequent LP sensitivity analyses. In these scenarios, the availability of an additional full-time farm operator or part-time seasonal labor was included in the model. The optimal acreage allocation given these scenarios was then determined.

RESULTS AND DISCUSSION

Here we present the results of the labor availability of a typical farm producer in eastern Nebraska throughout a given year, and the optimal distribution of labor and alternative crop enterprises generated by the LP model. The economic data associated used for and determined by the LP model are presented in Hoagland et al. (2009).

Labor Availability

Within a six-day week, a year in eastern Nebraska has a total of 3,754 daylight hours. However, because of weather conditions not all of these hours are available for field related activities. After adjusting for field conditions we determined that 172 days or 2,200 hours are available for field activities; and 140 days or 1,550 hours of labor available for non-field activities (Figure 1). A typical non-farm 40-hour work week totals 2,080 hours per year. Field availability corresponded with the growing season, beginning in mid-March, peaking June through September, and ending in late November (Figure 1). Non-field labor availability followed the opposite pattern.

A typical corn-soybean enterprise in eastern Nebraska requires a total of 943 hours of labor throughout the year (Table 1). However, only during planting and harvest was the labor of one full-time farm operator fully utilized in the corn–soybean enterprise (Figure 1). In contrast, there were significant time periods during the year where labor was underutilized, leaving 1,137 hours for either off-farm employment, assuming a typical non-farm 40-hour work week, or 1,727 hours of field time and 1,079 hours of non-field time for the production of supplemental crop enterprises on the farm.

Labor Distribution

The initial LP analysis examined each alternative separately in relation to the existing corn-soybean rotation. Subsequently, the alternative cropping

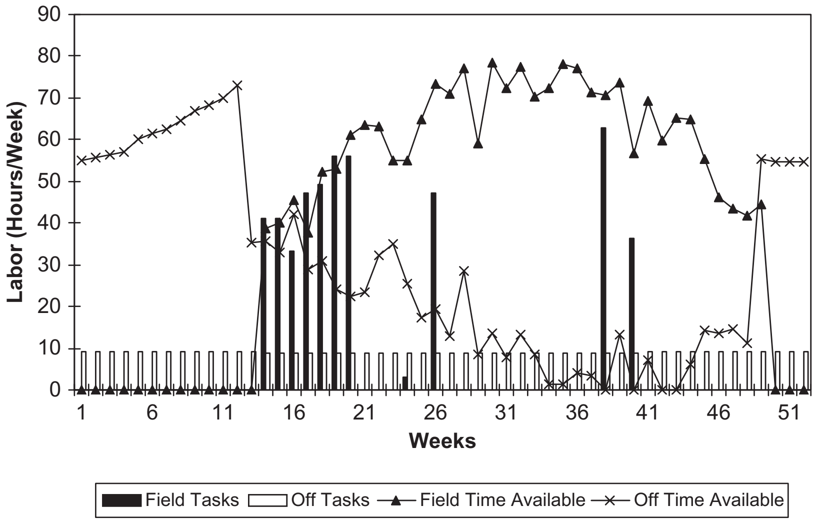

FIGURE 1 Tasks and labor schedule and distribution of labor by week for the production of the base 256-hectare corn-soybean farm enterprise.

scenarios were analyzed together in different combinations. The results indicate the optimal annual land allocation for each crop scenario given the overall constraints programmed in the model.

The full integration of livestock on the same land base has tremendous potential to increase the economic and environmental sustainability of a specialized grain production system (Sulc and Tracy, 2007). However, full integration of livestock would also require additional capital and labor investment on the part of the producer, and this strategy was beyond the scope of our analysis. Instead, we focused only on the integration of cattle grazing stalk residues. This strategy also has potential to increase the sustainability of a specialized grain crop system but without the investment requirements. As expected, this scenario improved the economic situation of the producer, (Hoagland et al., 2009) but did not change the labor allocation of the producer or the optimal crop acreage allocation in our analyses.

The integration of a Brassicaceaecrop such as cabbage into a rotation can enhance the agronomic performance of subsequent crops, reduce input costs, and reduce negative environmental impacts. Brassicacea crops are well known for their ability to suppress weeds and disease in a subsequent crop (Brown and Morra, 1997), and thus reduce the need for pesticide application. Additionally, inclusion of a Brassicacea crop can reduce nutrient loss. Weinert et al. (2002) found a winter Brassicacea cover crop to accumulate and thereby reduce leachable soil profile levels of nitrate-N over 100 kg ha^{-1}. Our results indicate that inclusion of a winter wheat/cabbage or spring cabbage/sunflower enterprise can also improve the profitability of a grain operation (Hoagland et al., 2009) and can make use of the underutilized labor available in this system.

Given the labor constraints of a single-operator farm, the integration of winter wheat–fall cabbage was the most feasible of the alternatives evaluated, and made the most use of available labor. The LP model allocated 8.1 ha in each given year to its production, successfully using an additional 357 hours of the available labor (Table 5). The integration of spring cabbage-sunflowers was also feasible; however, since both this option and the base farm had high labor requirements in the spring, the spring cabbage–sunflower alternative was constrained by available labor more than the winter wheat–fall cabbage integration option, allocating only 1.46 ha to its production and using only 65 hours of the under-utilized labor (Table 5). When the two cabbage options were considered simultaneously, the winter wheat–fall cabbage land allocation was reduced slightly and the spring cabbage–sunflower land allocation was increased (Table 5). This was due to labor shifted away from the corn–soybean rotation in favor of cabbage production. In this scenario, 430 hours of underutilized labor in the original corn–soybean base farm were utilized.

Windbreaks contribute to the profitability and environmental quality of grain crop systems by increasing crop yield and simultaneously reducing the levels of off-farm inputs (Brandle et al., 2004). The shelter provided by windbreaks reduces crop stress, controls erosion, disrupts disease, insect and weed seed movement, and provides habitat for beneficial insects and birds (Brandle et al., 2000). A windbreak system can also provide shelter for the production of high value woody floral crops (Josiah et al., 2004).

TABLE 5 Optimal Acreage Allocation Given the Linear Programming Results for a 256 ha Farming Enterprise

Option	Labor availability	C/S	WW/FC	SC/S	Land allocation (hectares) WB	SC	GW	BR	Total operator labor used
1	One ft operator	256	–	–	–	–	–	–	944 hrs
1 vs 2	One ft operator	247.9	8.1	–	–	–	–	–	1301.1 hrs
1 vs 3	One ft operator	254.5	–	1.5	–	–	–	–	1008.7 hrs
1 vs 4	One ft operator	255	–	–	3.8	0.1	0.13	0.02	1249.9 hrs
1, 2 & 3	One ft operator	246.2	8.1	1.6	–	–	–	–	1374.4 hrs
1,2,3 & 4	One ft operator	243.5	7.9	0.5	3.8	0.1	0.13	0.02	1511.9 hrs
1,2,3 & 4	Two ft operators	243.5	7.9	0.5	3.8	0.1	0.13	0.02	1511.9 hrs
1,2,3 & 4	One ft operator and pt help	233.2	8.3	10.2	3.8	0.1	0.13	0.02	1956.9 hrs

Option 1: Corn-soybean (CS); Option 2: Winter wheat/fall cabbage (WW/FC); Option 3: Spring cabbage/sunflower (SC/S); Option 4: Agroforestry—Windbreak (WB), Scarlet Curls Willow (SC), Goat Willow (GW), and Bailey Redtwig Dogwood (BR).

The labor requirements for site preparation and establishment of windbreaks and woody floral crops can be high, however maintenance requirements are minimal once established. Additionally, harvest labor requirements generally occur during the winter months, a time of low labor demand for corn–soybean production, suggesting that integration would be feasible. In our model, the agroforestry alternative was second best within the single comparisons, increasing profitability (Hoagland et al., 2009) and using 306 hours of the underutilized labor available in a corn–soybean farming system (Table 5). The LP model allocated a total of 0.25 ha to woody floral production. It should be noted that production of the woody floral crops was constrained not by labor availability, but by available markets in this region, which were assumed to be limited in this analysis.

When all of the alternative crop enterprises were evaluated in the LP model together, the labor allocated to cabbage production was reduced in favor of the available labor allocated to the higher value agroforestry crops (Table 5; Figure 2). In this scenario, the integration of the supplemental crop enterprise made use of 568 hours of underutilized labor.

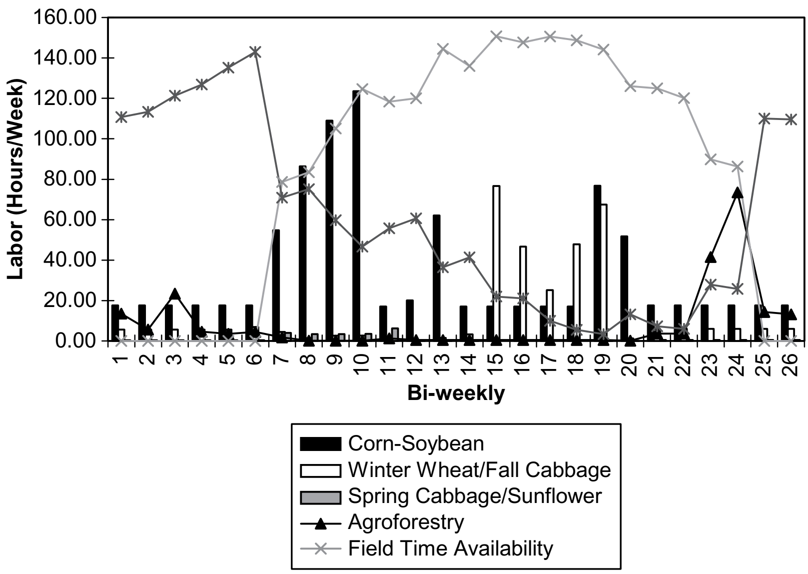

FIGURE 2 Optimal distribution of labor by week given all production options. (243.54 C-S, 7.88 WW/FC, 0.54 SC/S, 3.75 WB with 0.10 SC, 0.13 GW and 0.02 BR).

Note that in Figure 2 the field and non-field tasks of each option were combined to make the graph more easily readable. This allows production to occur where it may appear in the graph to be constrained by a given time availability category. However, the figure illustrates how the crop production was constrained by the total labor available in general.

Sensitivity Analyses

When additional labor was made available from a second full-time skilled operator, there were no changes in the optimal cropping allocation (Table 5). This was most likely due to the high cost of this additional labor, and the inability of any of the scenarios to fully utilize the additional labor throughout the year.

When additional part-time labor was added to the LP model during critical time periods, producer profitability increased dramatically (Hoagland et al., 2009), and 1,957 hours of the farm producer's underutilized labor was allocated to the production of supplemental crops (Table 5; Figure 3). Again, in this scenario, the production of the woody floral crops was constrained by market share and not labor availability. In contrast, the spring cabbage/sunflower alternative was increased significantly.

In this scenario198 hours of additional part-time seasonal labor was needed. As such, the operator would be faced with the option of adding additional part-time labor and transforming the farm into a more intensively managed operation. However, increasing farm size is accompanied by a reduction in rural populations resulting in labor shortages (Flora, 2001).

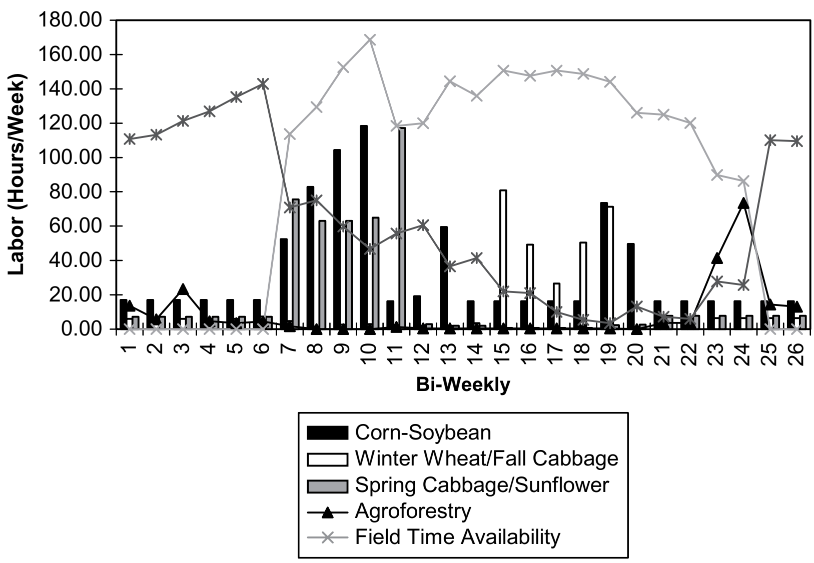

FIGURE 3 Optimal distribution of labor by week given all production options with additional part-time labor. (233.23 C-S, 8.32 WW/FC, 10.19 SC/S, 3.75 WB with 0.10 SC, 0.13 GW and 0.02 BR).

Note that in Figure 3 the field and non-field tasks of each option were combined to make the graph more easily readable. This allows production to occur where it may appear in the graph to be constrained by a given time availability category. However, the figure illustrates how the crop production was constrained by the total labor available in general.

Therefore, the producer may be constrained by the availability of part-time employees.

CONCLUSIONS

The integration of supplemental crops into a row-crop farming system has the potential to increase the agronomic, economic, and environmental sustainability of the operation. However, the reduced use of off-farm inputs is often associated with increased labor demands (Pfeffer, 1992) and labor can often be a limiting resource. In our study, the operator's labor in a typical corn–soybean operation is fully utilized only during planting and harvest periods, and a significant amount of labor could be utilized for the production of supplemental crops. All four alternative scenarios, when considered separately in comparison with the base farm, made greater use of the available labor (Table 5) and increased the profitability (Hoagland et al., 2009) of the farming enterprise. Our analysis of four alternatives indicated that supplemental crops with alternative labor schedules to the base corn–soybean farm can be successfully integrated into the typical 256 ha corn–soybean system.

While the grazing of stalk residues by a neighbor's cattle did not make use of the underutilized labor, it did increase profitability and could lead to synergies in production, such as reduced fertilizer needs. The full integration of livestock into a grain operation has great potential to make use of this underutilized labor and should be explored in further detail. Both cabbage options and the agroforestry option made use of the underutilized labor and increased profitability. However, the labor requirements of these alternative crops are quite high, making these options feasible only on a small scale. Additional seasonal part-time labor can dramatically increase the production opportunities for these alternative crops, yet declining population in rural communities may limit this option.

Overall, the integration of various alternative crops made use of underutilized labor within the farm operation and has potential to increase farm profitability and improve agronomic and environmental sustainability.

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