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Crop-Livestock Diversification and Efficiency in Agriculture

Diversification is a familiar strategy for managing risk in agriculture. It can take several forms including growing more than one crop or operating a farm with both crop and livestock enterprises. As with other strategies for managing risk, diversification comes with a unique set of costs. Managing a farm with multiple enterprises creates additional overhead as well as additional demands on management, labor, land, capital, and other resources. Diversification adds complexity to an operation and too much complexity can lead to inefficiencies.

However, diversification is a major strategy for managing risk. Diversification makes the most sense if complementarities and synergies exist between enterprises that lead to reduced variance in income with positive impacts on biological and financial resilience, in addition to creating various environmental benefits such as improving soil quality and sustaining food production.

Scientists argue that complementarities between crop and livestock enterprises can enhance nutrient cycling and provide ecosystem services with long-run positive impacts (Moraine et al., 2017). However, it is important to understand all the tradeoffs of adopting an integrated crop-livestock production system, including the effect this diversification may have on production efficiency, particularly in the short run. Diversification of agricultural activities could pose managerial challenges related to resources allocation across multiple enterprises which suggests that diversification is a learning process strictly influenced by the surrounding environmental context.

In a recent study, we evaluated the technical efficiency of integrated crop-livestock systems (ICLS) on a county-wide basis in Nebraska in comparison to specialized cropping systems and specialized livestock systems (Afi and Parsons, 2023). To accomplish this task, we created a typology of Nebraska counties dividing them into three classifications based on agricultural production sales. Using 2017 Ag Census data, we classified 38 Nebraska counties as ICLS counties with livestock sales making up 40 to 70 percent of total agricultural sales. We classified 22 counties with livestock sales greater than 70 percent of total sales as specialized livestock counties. The remaining 33 counties were classified as specialized cropping counties.

We then used an output-oriented data envelopment analyses (DEA) to create an efficiency frontier for each subgroup to identify those counties that are fully efficient which translates to producing the maximum agricultural output for their given level of input. For example, for the 22 specialized livestock counties, the inputs into the system were defined as number of cattle, agricultural land area, expenditures on feed, and agricultural labor expenses. The output of net income ranged from a low of \$2.8 million to a high of \$168 million with an average of \$39 million across the 22 counties. We classified 8 of the 22 counties as members of the efficiency frontier (Cherry, Cuming, Grant, Hooker, Loup, Morrill, Phelps, and Sioux). For the 14 livestock specialized counties not on the frontier, the efficiency scores ranged from 0.19 to

0.88 (on a scale from 0 to 1) with an average score of 0.61. Fully efficient counties tended to have a large percentage of cattle on feed (i.e., Cuming County) or be located in or near the Sandhills. The most inefficient livestock specialized counties tended to be grass-based production counties with lower stocking rates as defined by Cumming et al. (2019).

For the 33 cropping specialized counties, the inputs into the system were defined as agricultural land area, expenditures on chemicals, and agricultural labor expenses. The output of net income ranged from a low of $7.4 million to a high of $84 million with an average of $44 million. We classified 10 of the 33 counties as members of the efficiency frontier (Cass, Dodge, Douglas, Johnson, Kimball, Pawnee, Richardson, Sarpy, Seward, and Washington). Higher chemical expenditures tended to be correlated with higher efficiency scores for cropping specialized counties.

For the 38 ICLS counties, we combined the inputs for the livestock systems counties and cropping systems to obtain a list of five inputs (land area, number of cattle, and expenditures on chemicals, labor, and feed). The output of net income ranged from a low of $4.9 million to a high of $125 million with an average of $47 million. We classified 14 of the 38 counties as members of the efficiency frontier (Boyd, Clay, Colfax, Deuel, Dixon, Hall, Harlan, Keya Paha, Logan, Pierce, Platte, Polk, Sheridan, and Thurston). For the 24 ICLS counties not on the frontier, the efficiency scores ranged from 0.13 to 0.97 with an average score of 0.68. Several interesting factors emerged with respect to the fully efficient ICLS counties. For example, unlike cropping specialized counties, fully efficient ICLS counties tended to spend less on chemicals than the less efficient ICLS counties. Also, the share of irrigated crop land and the share of pastureland tended to be higher in fully efficient ICLS counties compared to the less efficient ICLS counties. These characteristics seem to suggest the most efficient ICLS counties are capturing some of the synergies of crop-livestock diversification with efficient use of perennial grass coupled with crop residue grazing more typically found in irrigated systems.

Finally, we took all 93 counties and created a meta-frontier. The mean technical efficiency score for the 93 counties was 0.74. We identified a total of 23 counties on the meta-frontier. Of the 8 counties on the frontier for the livestock specialized counties, six made it to the meta-frontier with only Morrill and Phelps County dropping out because other cropping specialized or ICLS counties with similar inputs produced more output (net income). One livestock specialized county, Brown County, which was not on the frontier when compared to other livestock specialized counties excluding chemical expenditures as an input was on the meta-frontier comparing all 93 counties but including chemical expenditures.

For the cropping specialized counties, 8 of the 10 counties classified on the frontier when compared to other cropping specialized counties also appeared on the meta-frontier for all 93 counties. Only Kimball and Johnson counties did not make the meta-frontier with technical efficiency scores of 0.57 and 0.96, respectively. Interestingly, five cropping specialized counties appear on the meta-frontier that did not appear on the frontier comparing them to other cropping specialized counties. So, cropping specialized counties made up a majority of the counties (13 out of 23) on the meta-frontier.

Finally, only three of the ICLS counties appeared on the meta-frontier (Logan, Platte, and Polk). Furthermore, the average technical efficiency score for the ICLS counties in the meta-frontier analysis was 0.67, compared to 0.84 for cropping specialized counties and 0.73 for livestock specialized counties.

This work is just the first step in gaining a better understanding of the technical efficiency of integrated crop-livestock systems. Our study was limited by the use of secondary data at the county level, but it does seem to suggest there is an efficiency loss associated with the diversification into integrated crop-livestock systems. This result promotes the necessity for further research toward obtaining a better understanding of the synergies and complementarities between crops and livestock for an enhanced and more efficient implementation of integrated systems. Research is currently underway examining farm-level data to gain a better understanding of the determinants of technical efficiency and the role of diversified crop-livestock systems in contributing to sustainable food production.

This article is a summary of:

Afi, M. and J. Parsons. 2023. Integrated vs. Specialized Farming Systems for Sustainable Food Production: Comparative Analysis of Systems' Technical Efficiency in Nebraska. *Sustainability*, **15**:5413. https://doi.org/10.3390/su15065413.

Other References Cited:

Cumming, K., J. Parsons, W. Schacht, and B. Baskerville. 2019. Examining the Capacity of Nebraska Rangelands for Cattle Production. *Western Economics Forum*, **17**:46-61.

Moraine, M., M. Duru, and O. Therund. 2017. A Social-Ecological Framework for Analyzing and Designing Integrated Crop-Livestock Systems from Farm to Territory Levels. *Renew. Agric. Food Syst.*, **32**: 43-56.

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