Impact of Production Diversification on Farm Resilience: Evidence from Kansas Farms

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2024 Risk and Profit Conference

K-STATE Research and Extension

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Motivation : Why Study Diversification ?

Diverse Crops Bring Diverse Benefits

- **Environmental:** Soften impacts on environmental resources
- **Social**: Create new industries based on agriculture, strengthening rural communities
- **Economic**: Aid the domestic economy, enabling producers to grow crops that would otherwise be imported

Too little research on how diversification

Benefits Farmers Profits.

Diversification for Farm Financial Resilience

Agricultural Challenges:

Farmers face risks from adverse weather, pests, diseases, and market fluctuations.

Production Diversification:

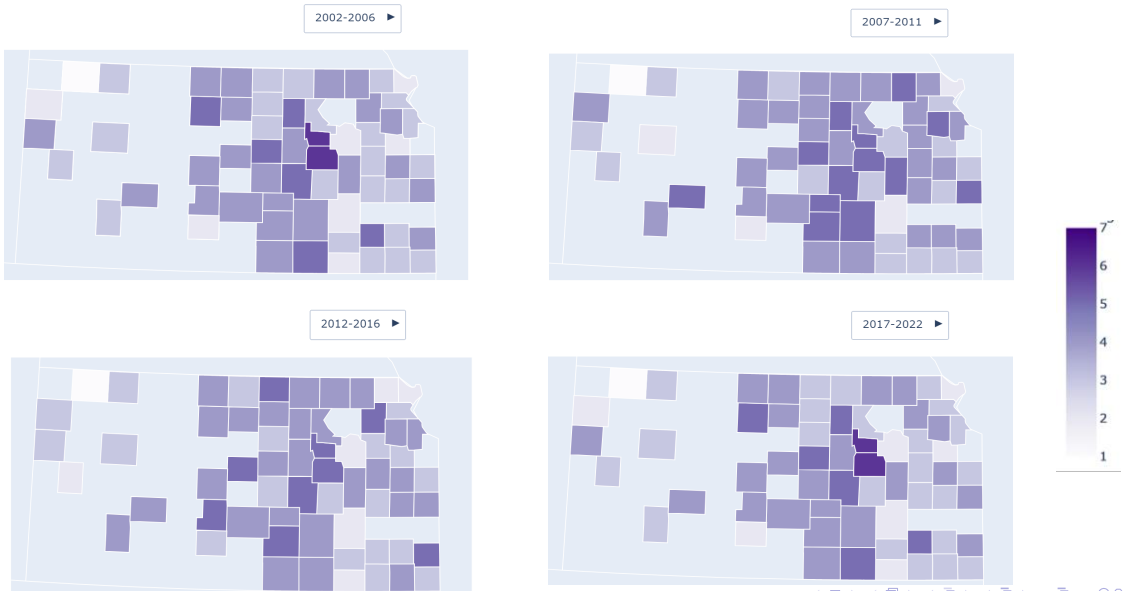
Recognized as an effective strategy to stabilize returns.

System Resilience:

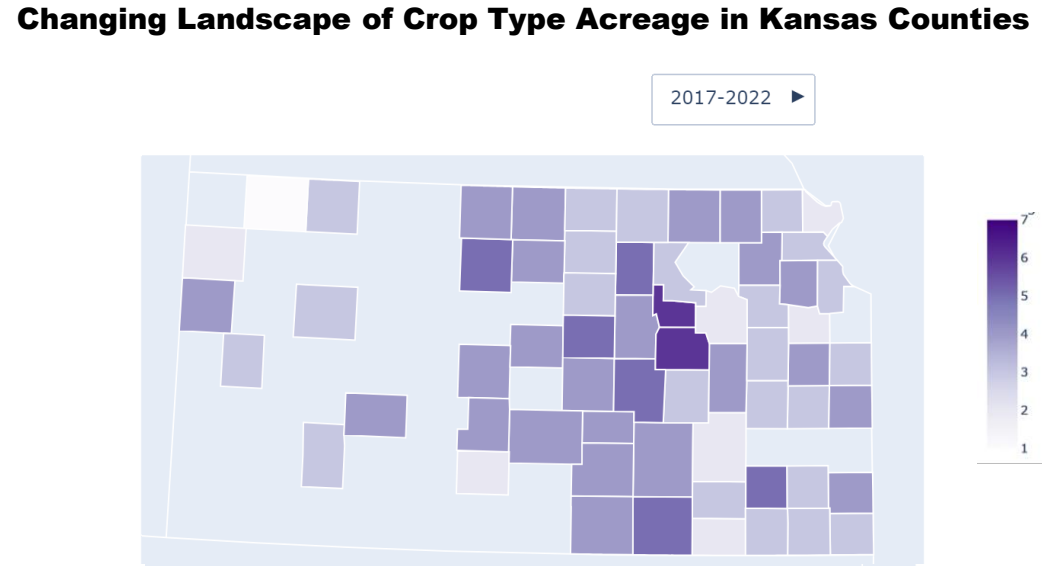
A socio-ecological system's ability to adapt to disturbances.

Motivation

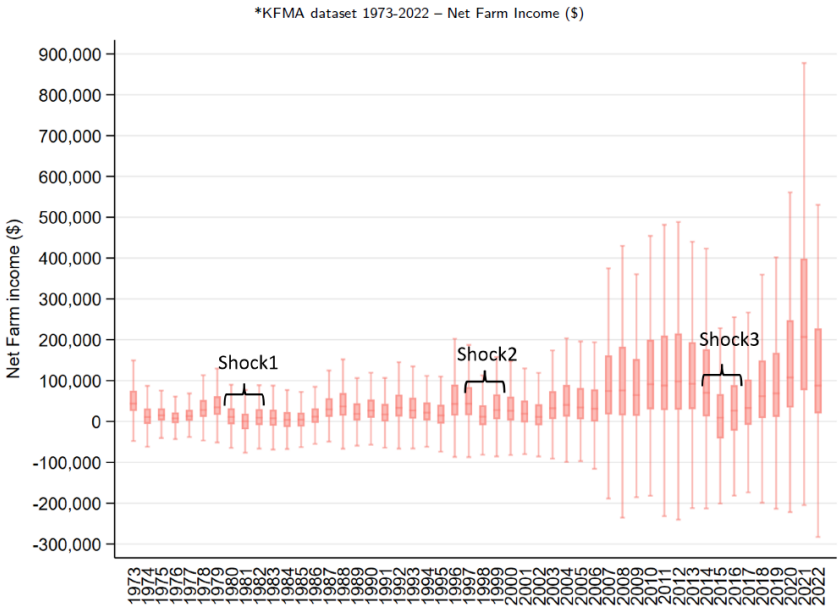
Changing Landscape of Crop Type Acerage in Kansas Counties



Motivation


Changing Landscape of Crop Type Acreage in Kansas Counties
2017-2022
7
6
5
4
3
2
1

Kansas Net Farm Income



Shock 1 – 1980 Drought
Shock 2 – 1999 Drought in SE
Shock 3 – 2012 Drought

Research Objective and Hypothesis

Objective: Investigate the impact of production diversification on farm income, specifically its role in enabling farms to withstand environmental shocks.

Hypothesis: Crop diversification dulls the negative effects of shocks on farms' financial health.

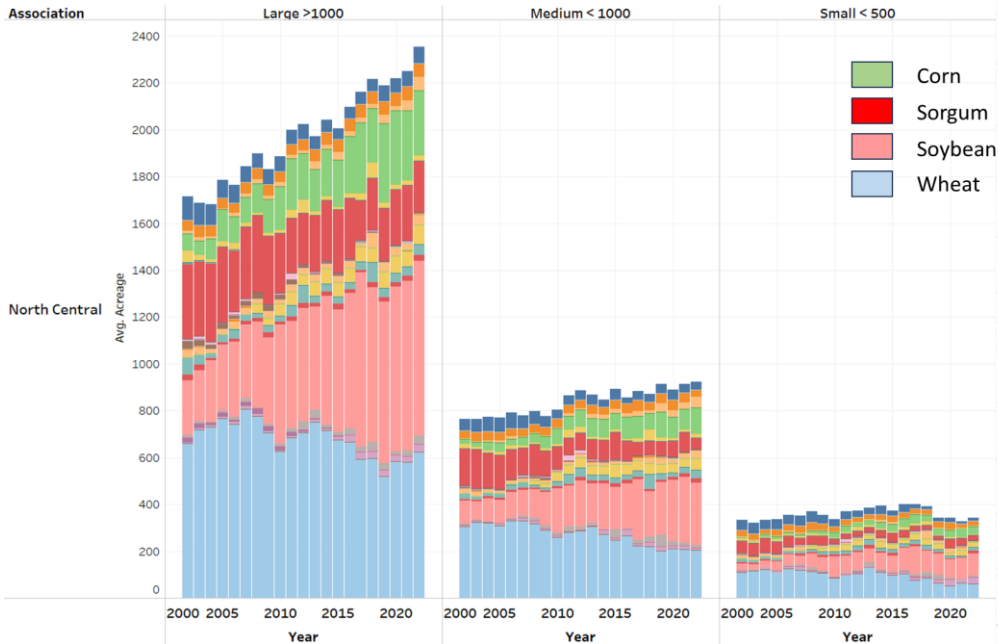
- A. Analyze crop vs mix farm (crop + livestock) diversification effect on farm income
- B. Analyze within crop diversification effect on farm income

Kansas Farm Management Association (KFMA) data

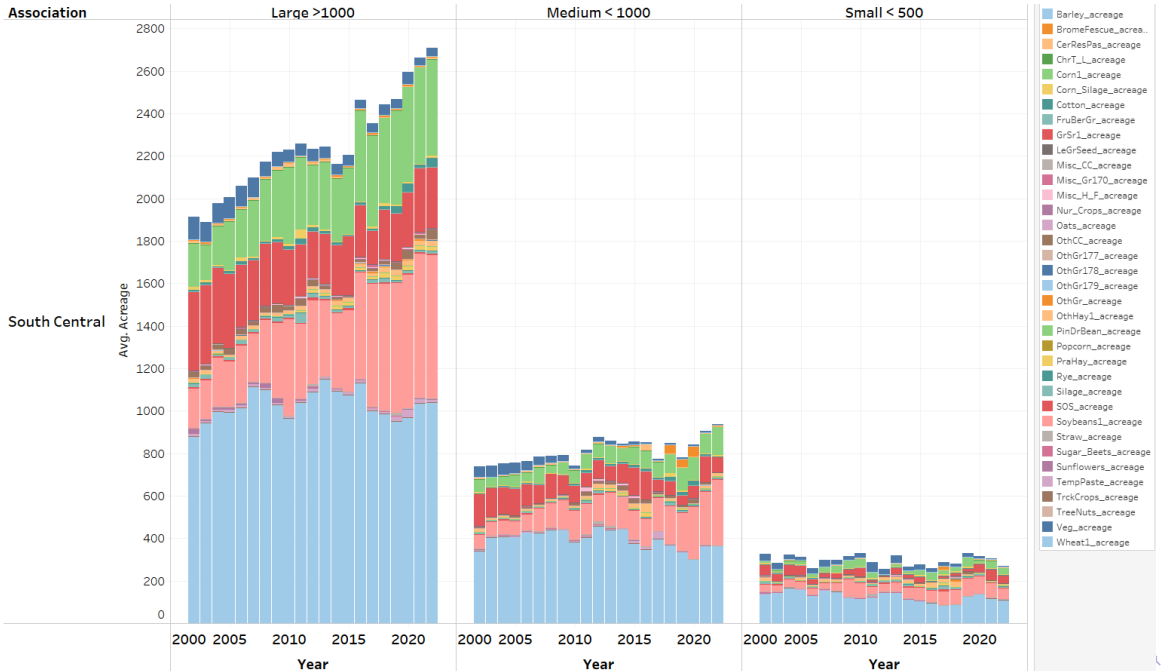
- **Data Overview:**
  - Annual compilation of Kansas farms data that includes a diverse set of variables, including income, balance sheet ratios, production, and operational metrics.
  - Timeframe spans from 1973 to 2022, covers various periods by economic and environmental shocks.

- **Relevant Data:**
  - Year 2002 - 2022(21 years) (232 Kansas farms)
  - Detailed data on assets, including production, inventory, net farm income, debt, and expenses
  - **North Central (73, 31%),** Southeast (61, 26%), Northeast (56, 24%), South Central (29, 13%), Southwest (7, 3%), Northwest (6, 3%)
  - Livestock only farms (1%), crop only (29%), and both livestock and crop (70%) types of farms.

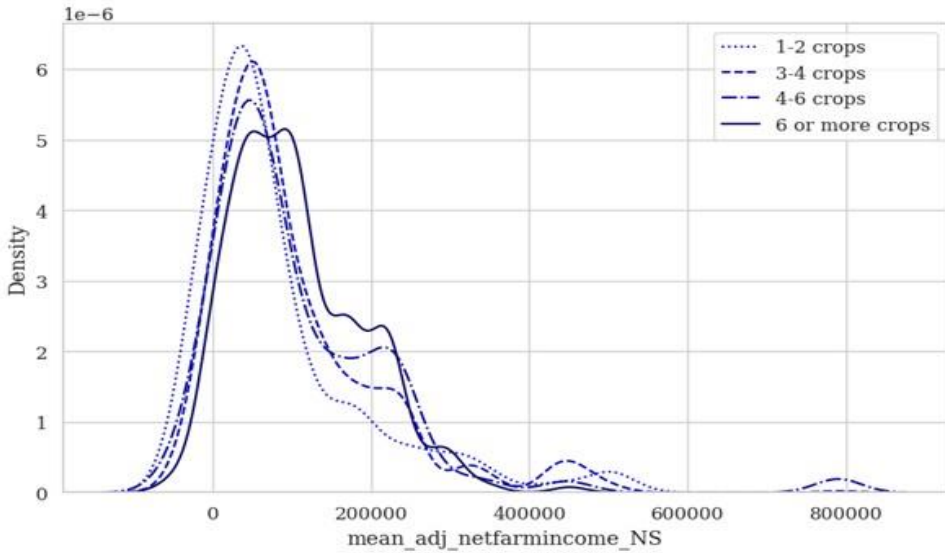
North Central



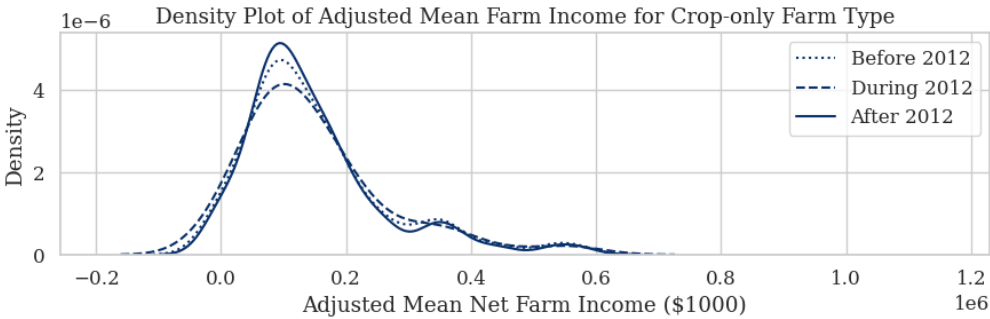
South Central

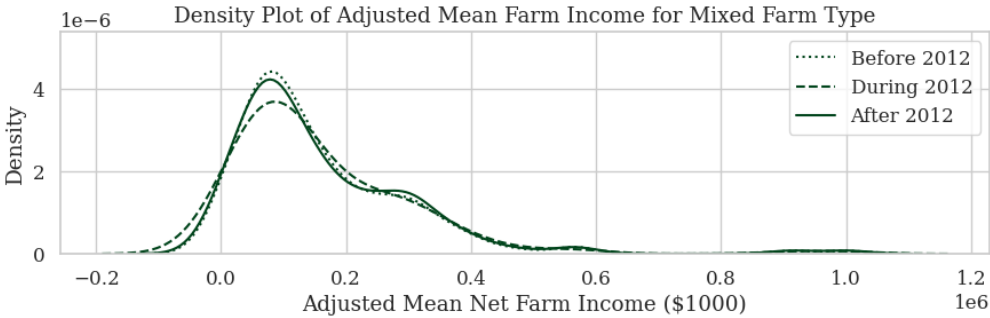


Density Distribution of Adjusted Net Farm Income Across Farm Type



Farm Type Effects Before and After Shock





Methodology – Two Way Fixed Effects Panel Data Model

Our methodological approach employs a two-way fixed effects panel data model.

The baseline model is specified as follows:

$$y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 S_{it} + \beta_3 (D_{it} \times S_{it}) + \gamma X_{it} + \alpha_i + \lambda_t + \epsilon_{it}$$

Where,

- y_{it} represents the inverse hyperbolic sine (IHS) transformed adjusted net farm income for farm i in year t.
- D_{it} denotes the drought measure
- S_{it} represents the crop diversity measure.
- X_{it} is a vector of control variables (farm size, location, total assets).
- α_i captures farm-specific fixed effects.
- γ_t captures time-specific effects
- ϵ_{it} is the error term.

Crop Diversification(D)

Diversification Index	Formula
Herfindahl-Hirschman Index (HHI) for Acreage	$\mathbf{HHI_{acreage}} = \sum(\mathbf{share}_{i,\mathbf{acreage}})^2$
Shannon Diversity Index (SDI) for Acreage	$SDI_{\text{acreage}} = -\sum(share_{i,\text{acreage}} \times \ln(share_{i,\text{acreage}}))$
Crop Share Threshold Count (by Income)	$\text{Count}_{\text{income}}(share_{i,\text{income}} > 0.10)$
Crop Share Threshold Count (by Acreage)	$\text{Count}_{\text{acreage}}(share_{i,\text{acreage}} > 0.10)$

Note: Indices are computed to reflect the level of diversification.

- The Herfindahl-Hirschman Index (HHI) indicates the concentration of acreage or income among crops, higher values indicating less diversification.
- The Shannon Diversity Index (SDI) reflects the diversity of crops, with higher values indicating greater diversification.
- The Crop Share Threshold Counts tally the number of crops making atleast 10% of the total acreage or income.

Drought Severity and Coverage Index (DSCI*)

US Drought Monitor measures DSCI as a weekly measure of drought intensity and spatial extent.

Intensity classes

Category	Drought Intensity Level	Percentile
D0	Abnormally dry	20 to 30
D1	Drought, moderate	10 to 20
D2	Drought, severe	5 to 10
D3	Drought, extreme	2 to 5
D4	Drought, exceptional	less than 2

** Jointly by USDA, National Oceanic and Atmospheric Administration (NOAA), National Drought Mitigation Center (NDMC) ;* Akyuz, F. A. 2017 ;*Kuwayama et al 2018 (ag.)*

Methodology – Conceptual Strategy

We estimate **Two variations of the model** to provide a comprehensive analysis:

- HHI with DSCI
- HHI with individual drought levels (D0-D4)

- Predict farm income using the estimated fixed effects and mean HHI Index (diversification baseline).
- Analyze the effect of change in diversification levels on farm income prediction (increased diversification scenario +0.1, +0.2).

Results

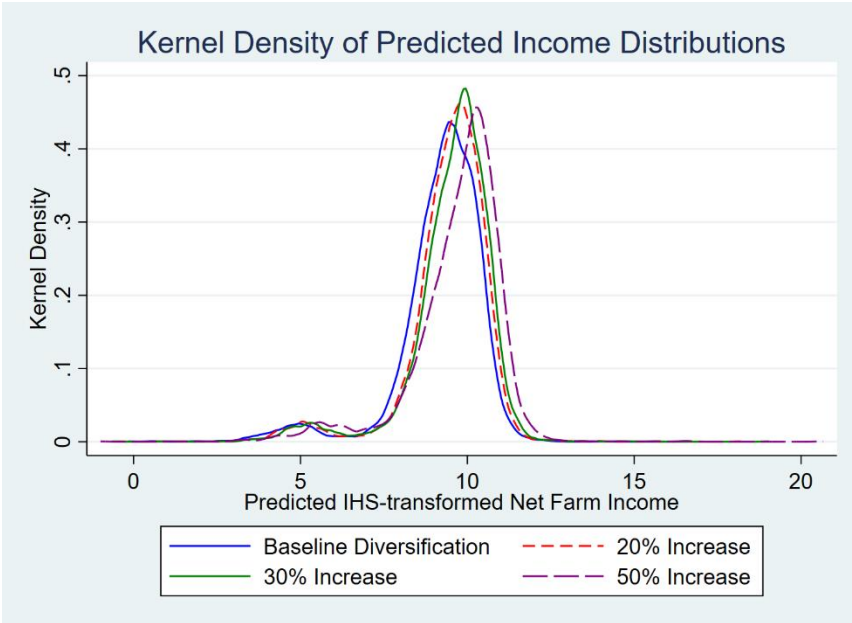
Table: Impact of Crop Diversity and Drought on Farm Income

	(1) HHI & DSCI	(2) HHI & Levels
HHI	-2.528*	-2.540
	(1.379)	(1.803)
DSCI	-0.000**	
	(0.000)	
D2		-0.116***
		(0.036)
D4		-0.129***
		(0.048)
HHI × D4		0.177**
		(0.075)
Crop Acres	0.001***	0.001***
	(0.000)	(0.000)
Debt-to-Asset Ratio	-3.824***	-4.038***
	(0.729)	(0.720)
Govt Payments (lag)	-0.067	-0.074
	(0.071)	(0.071)
Insurance Income (lag)	-0.038	-0.033
	(0.026)	(0.027)
Insurance Expense (lag)	0.036	0.025
	(0.062)	(0.062)
Constant	8.923***	9.244***
	(1.082)	(1.198)
Observations	4,624	4,394

Note: Standard errors in parentheses. * pj0.10, ** pj0.05, *** pj0.01. All models include year and association fixed effects. Dependent variable: IHS-transformed adjusted net farm income. Standard errors clustered at farm level in parentheses.

Herfindahl-Hirschman Index (HHI) has a marginally significant negative impact when considering drought interactions.

Predicted Mean Income distribution



Thank you

Summary Statistics

Variable	1-2 crops	3-4 crops	4-6 crops	6 or more crops
Observations	671	1761	1382	1058
Crop Acres	1226.0 (945.4)	1451.5 (1161.0)	1457.9 (1044.3)	1479.2 (1005.9)
Debt-Asset Ratio	0.244 (0.260)	0.228 (0.247)	0.244 (0.233)	0.262 (0.225)
Farm Production Value ($k)	578.0 (549.0)	708.0 (684.0)	687.0 (643.0)	738.0 (606.0)
Net Farm Income ($k)	128.0 (207.0)	164.0 (230.0)	157.0 (228.0)	166.0 (200.0)
Government Payments ($k)	33.4 (41.5)	42.2 (51.9)	40.2 (43.9)	44.2 (48.6)
Insurance Income ($k)	27.1 (71.6)	32.9 (89.4)	32.2 (96.8)	30.1 (72.3)
Insurance Expense ($k)	16.7 (22.9)	19.2 (23.4)	17.2 (21.7)	16.8 (19.0)
Net Farm Income (No Gov Support) ($k)	83.8 (210.0)	108.0 (223.0)	102.0 (218.0)	108.0 (199.0)
Total Livestock Income ($k)	103.0 (291.0)	97.5 (251.0)	190.0 (483.0)	286.0 (502.0)
Farm Income Per Acre ($)	112.4 (298.9)	123.7 (170.7)	112.8 (153.6)	124.1 (143.0)
F.I. (No Support) Per Acre ($)	71.3 (301.6)	84.3 (176.2)	74.6 (152.1)	85.8 (144.5)

Summary Statistics

Variable	Crop-only (2002)	Mixed (2002)	Crop-only (2022)	Mixed (2022)
Age				
Age	48.93 (10.57)	49.55 (9.04)	68.98 (9.13)	66.74 (8.91)
Farm Characteristics				1502.71
Crop Acres	1433.78 (904.51)	1189.31 (857.91)	1424.40 (1034.33)	(1291.58)
Debt-Asset Ratio, Year End	0.42 (0.47)	0.38 (0.28)	0.09 (0.14)	0.16 (0.14)
Adjusted Financials				
Value of Farm Prod.($k)	327.77 (269.55)	389.83 (365.64)	737.85 (652.89)	941.04 (899.31)
Net Farm Income ($k)	49.39 (72.76)	49.29 (109.43)	176.80 (225.87)	184.42 (223.97)
Gov Payments ($k)	22.86 (19.64)	27.08 (19.68)	13.81 (27.16)	14.81 (33.24)
Crop Insurance Inc. ($k)	27.46 (40.35)	24.82 (41.36)	98.88 (135.26)	102.19 (227.32)
Crop Insurance Exp. ($k)	9.84 (12.79)	5.49 (7.55)	26.08 (26.79)	23.92 (26.43)
Farm Inc. per Acre	33.02 (53.58)	49.68 (155.41)	111.98 (114.17)	141.95 (202.28)
Farm Inc. no supp. Per Acre	4.20 (60.91)	0.65 (148.62)	51.94 (150.77)	94.13 (219.08)
Diversification				
Characteristics				
Crop Count Above 0 acres	3.73 (1.67)	5.38 (2.11)	3.11 (1.28)	5.50 (2.51)
Crop Count by 10% Inc.	2.71 (0.87)	3.05 (0.96)	2.37 (0.76)	2.62 (0.84)
Crop Count by 10% Acr.	2.84 (1.00)	2.94 (0.86)	2.46 (0.74)	2.94 (0.90)
Crop Acreage Diversity	0.57 (0.17)	0.65 (0.13)	0.53 (0.17)	0.64 (0.16)
Crop Income Diversity	0.57 (0.17)	0.64 (0.15)	0.50 (0.19)	0.58 (0.18)

Diversification Measures - Mean, SD, Min, and Max

Table: Descriptive statistics for diversification indices in 2002 and 2022.

	2002			2022		
Variable	Mean (SD)	Min	Max	Mean (SD)	Min	Max
HHI (Acreage)	.3675 (.1437)	0	1	.3986 (.1768)	0	1
HHI (Income)	.3689 (.1544)	0	1	.4477 (.1872)	0	1
SDI (Acreage)	1.2027 (.3809)	0	2.0936	1.1095 (.4443)	0	2.2224
SDI (Income)	1.2318 (.3810)	0	2.0394	.9893 (.4141)	0	1.9553
Crop Share Count (Income)	2.9 (.9711)	0	6	2.5 (.8322)	0	5
Crop Share Count (Acreage)	2.9 (.9067)	0	6	2.7 (.8899)	0	5

Key Observations:

- The HHI measures have slightly increased from 2002 to 2022, indicating a trend towards greater concentration in both acreage and income.
- SDI measures have decreased over the same period, reflecting the same trend.
- The decrease in crop share count for share at least 10% for income from 2002 to 2022.

Distribution of Crop Share Count by Income and Acreage

Table: Comparison of Crop Share Count for Income and Acreage between 2002 (2022).

Count by Income	Count by Acreage 0	1	2	3	4	5	6	Total
0	1 (1)	0	0 (0)	0 (0)	0 (0)	0 (0)	0	1 (1)
1	0	5 (10)	2 (8)	1 (0)	0 (0)	0 (1)	0	8 (19)
2	0	3 (1)	38 (65)	18 (28)	5 (5)	0 (1)	0	64 (100)
3	0	0	22 (8)	57 (63)	17 (13)	2 (3)	0	98 (87)
4	0	0	6 (2)	18 (6)	22 (13)	1 (2)	0	47 (23)
5	0	0	0	4 (1)	5 (0)	3 (1)	0	12 (2)
6	0	0	0	0	1 (0)	0 (0)	1	2 (1)
Total	1 (1)	8 (11)	68 (83)	98 (98)	50 (31)	6 (8)	1	232 (232)

Key Insights:

- Majority of farms have two to four crops each accounting for more than 10% of their income and acreage.
- A very small number of farms reach above 5 level of diversification across both income and acreage.

Comparative Analysis of Diversification Indices

Farm	Type	Crops	SDI	HHI
1	33%, 33%, 34% (Balanced)	3	1.098	0.2189
2	80%, 10%, 10% (Unbalanced)	3	0.639	0.66
3	20% each (Balanced)	5	1.609	0.2
4	50%, 25%, 15%, 5%, 5% (Unbalanced)	5	1.284	0.3275

- Shannon Index more sensitive to changes in crop distribution, accurately reflecting diversification levels.
- Adaptable across different scales