Crop Rotations and Dynamic Marginal Adjustment to Sustainable Incentives

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UC Davis

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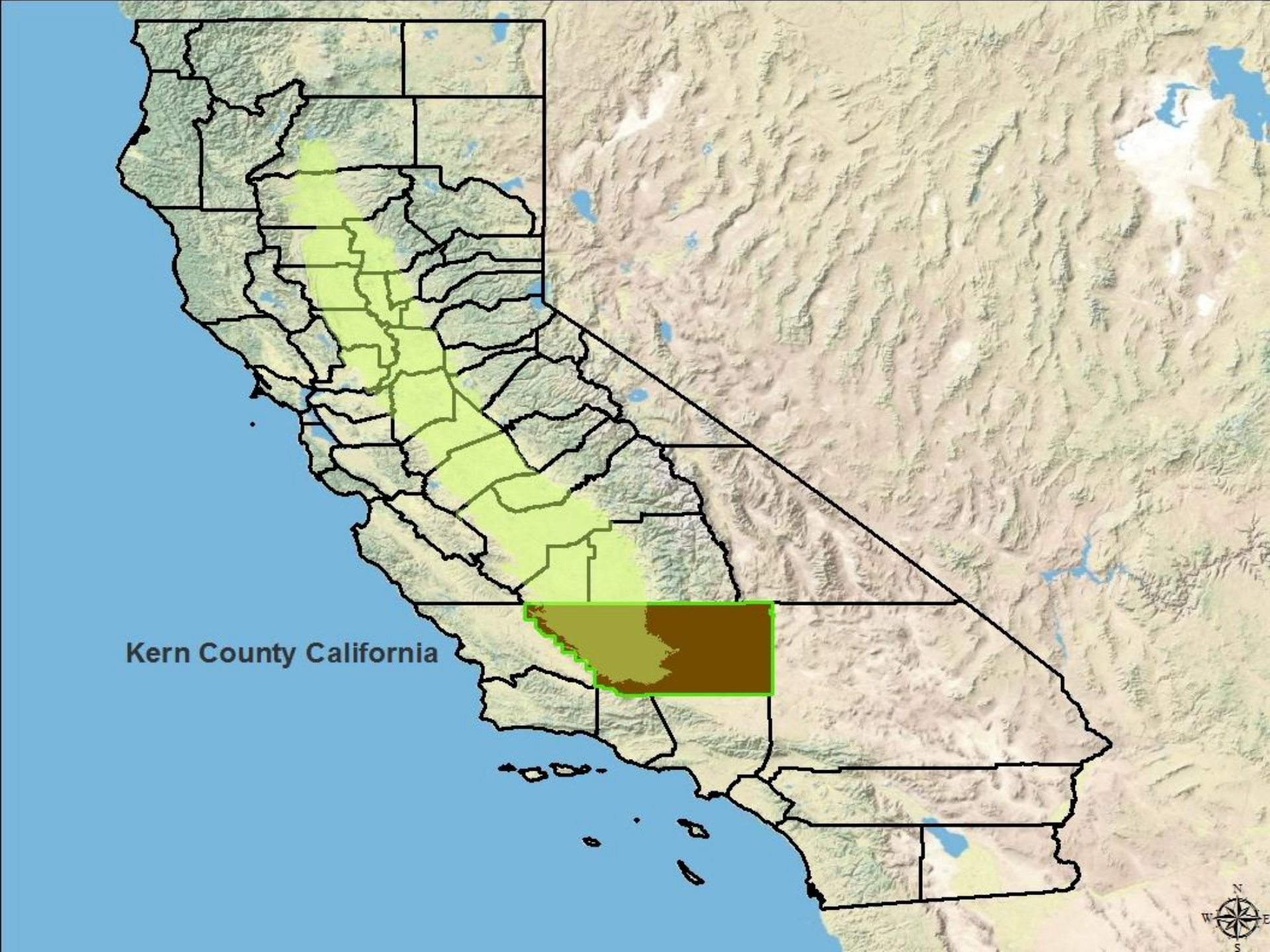
Outline

- **Crop Rotations Offer an Alternative Path to Sustainability**
  - **Dynamic Margin Adjustment**
  - **Dynamic Agronomy well known**
  - **Dynamic Economics Rarely Studied**
- **Economics of Crop Switching are Key**
  - **Formidible data requirements**
  - **Difficult micro capital theory**
  - **Ill posed estimation problems**
- **A Dynamic Field Level Model**
  - **Identifying rotations from 14,229 fields for 12 years**
  - **Estimating parameters**
  - **Solving the dynamic program**
- **Extensions**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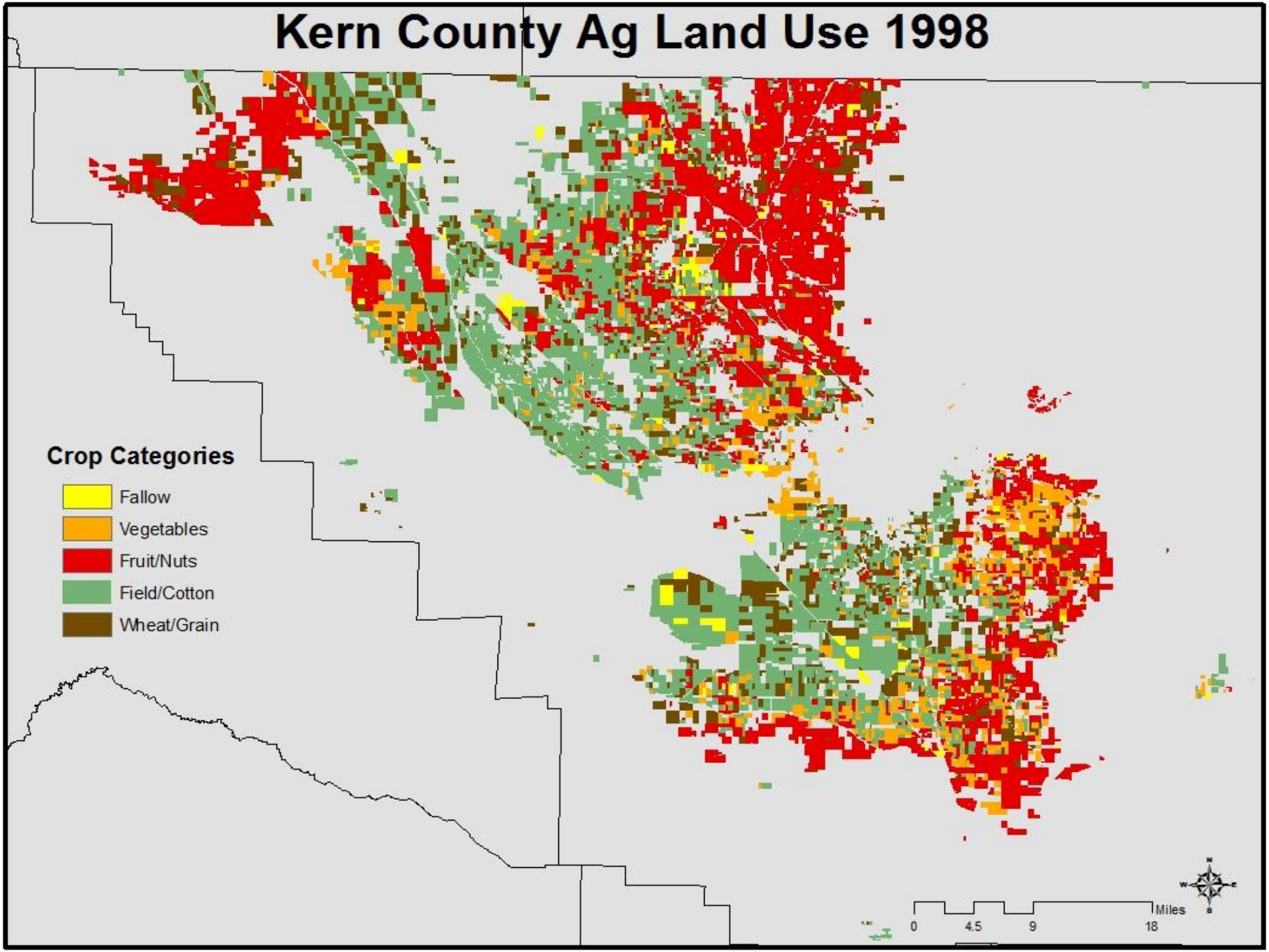
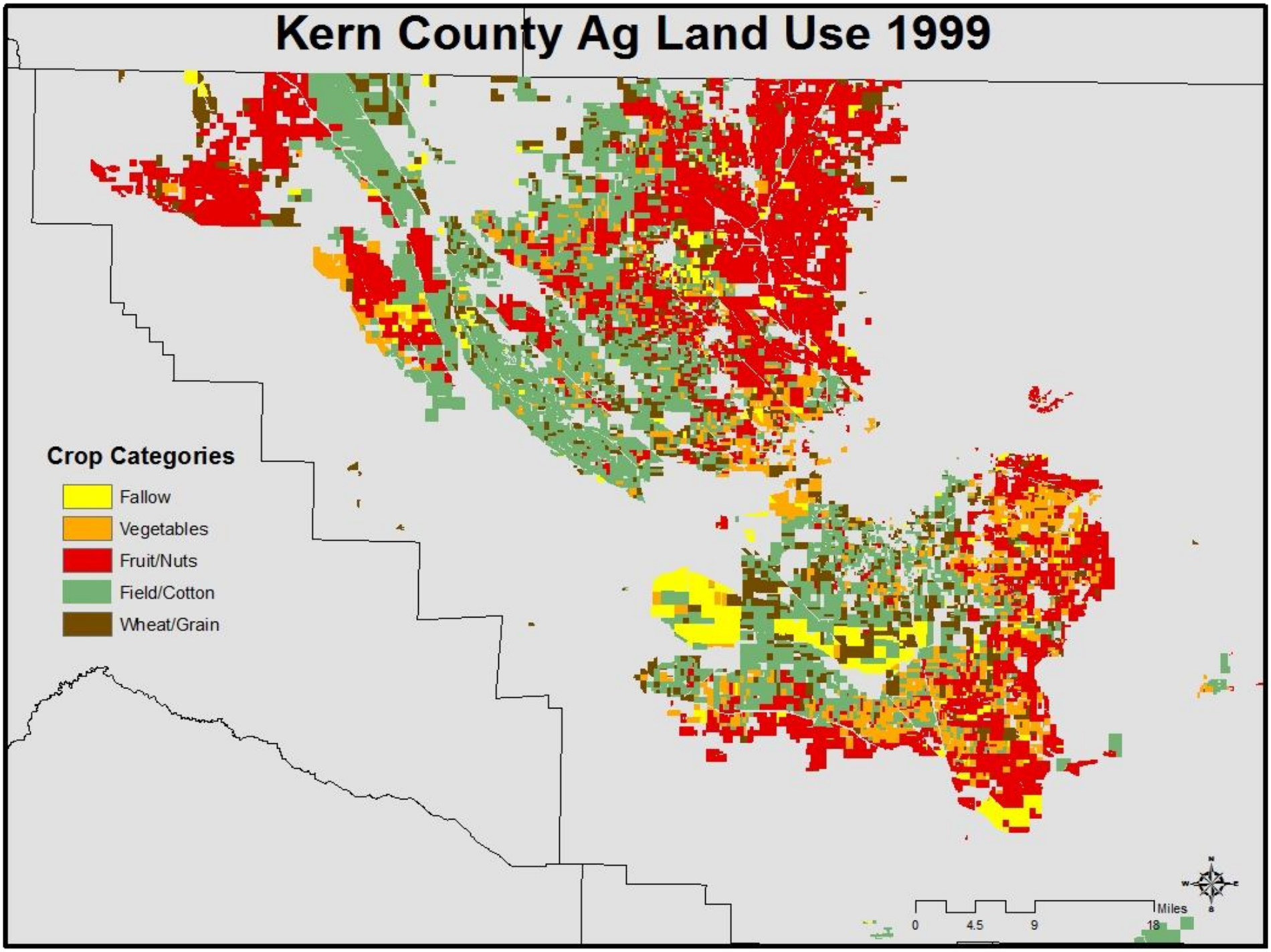
Kern County Ag Land Use 1998



Kern County Ag Land Use 1999



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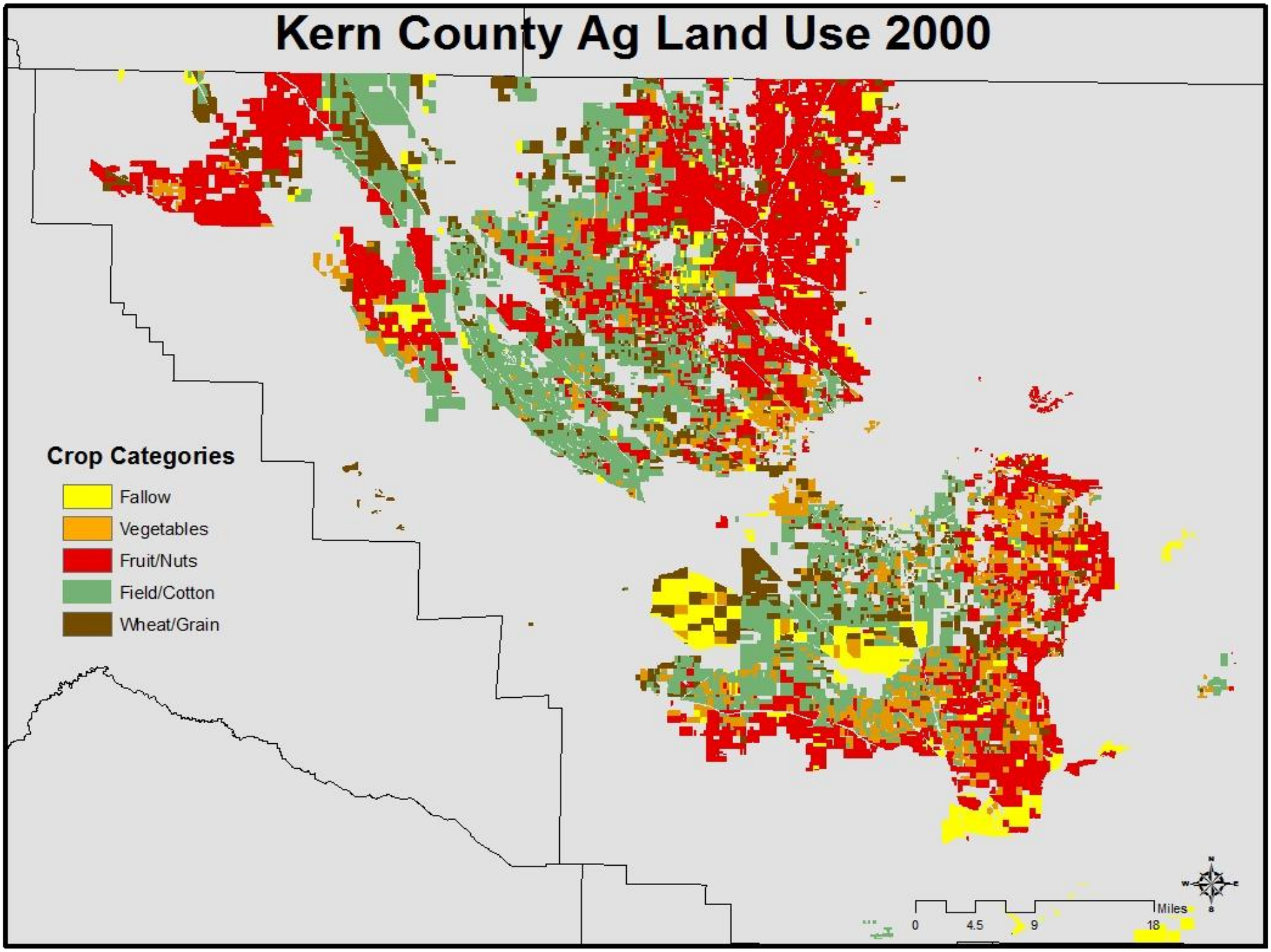

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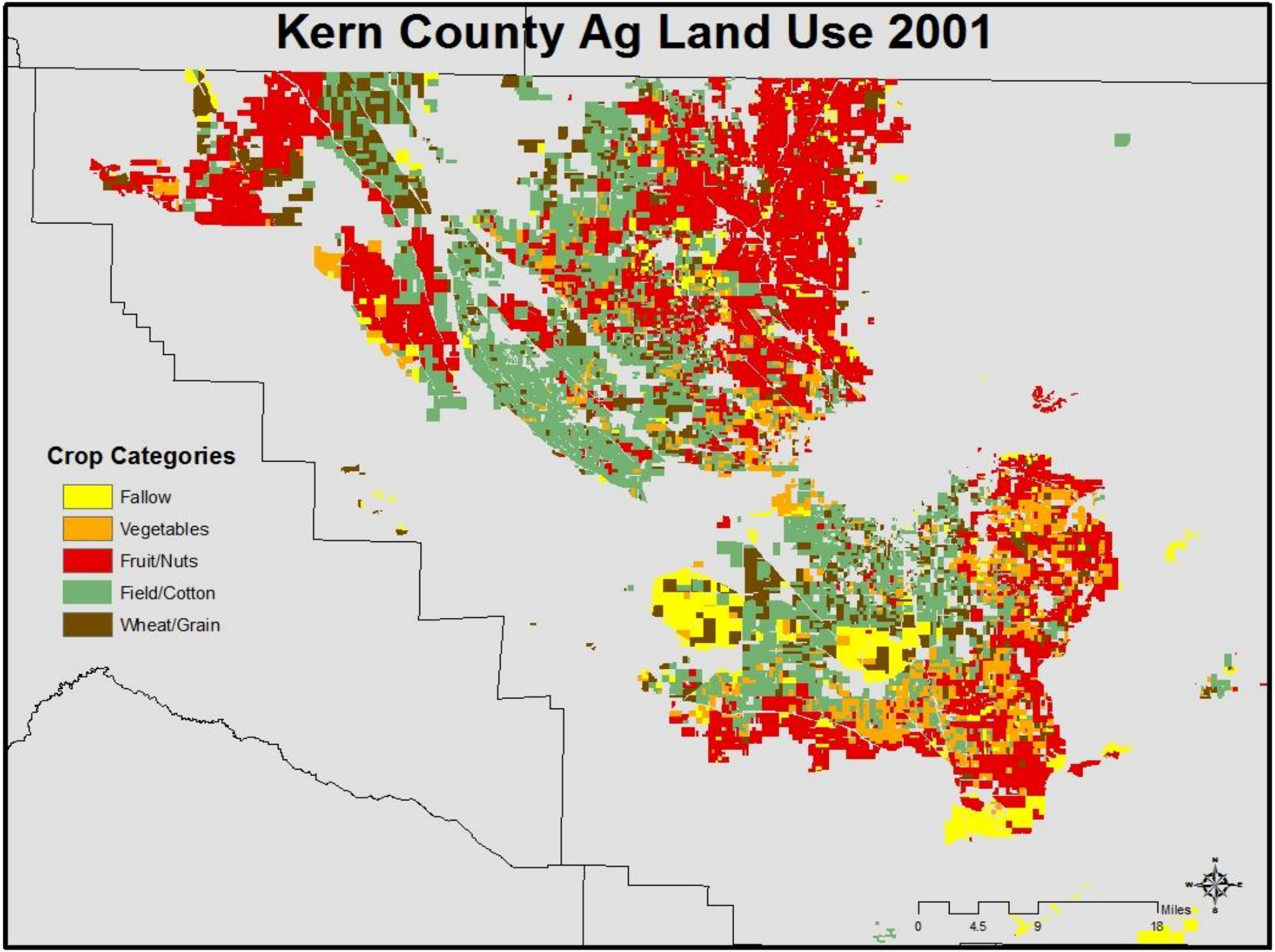

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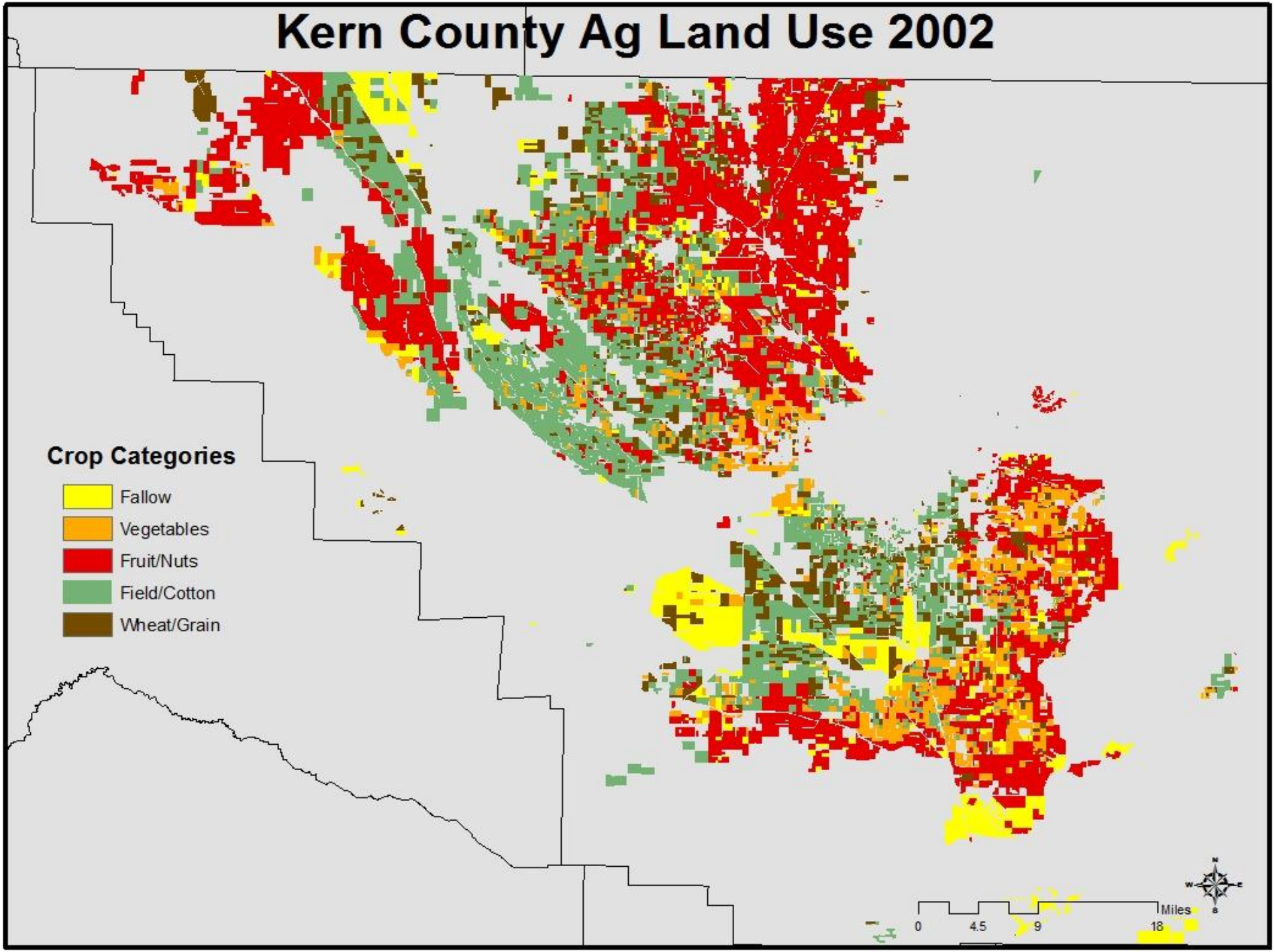

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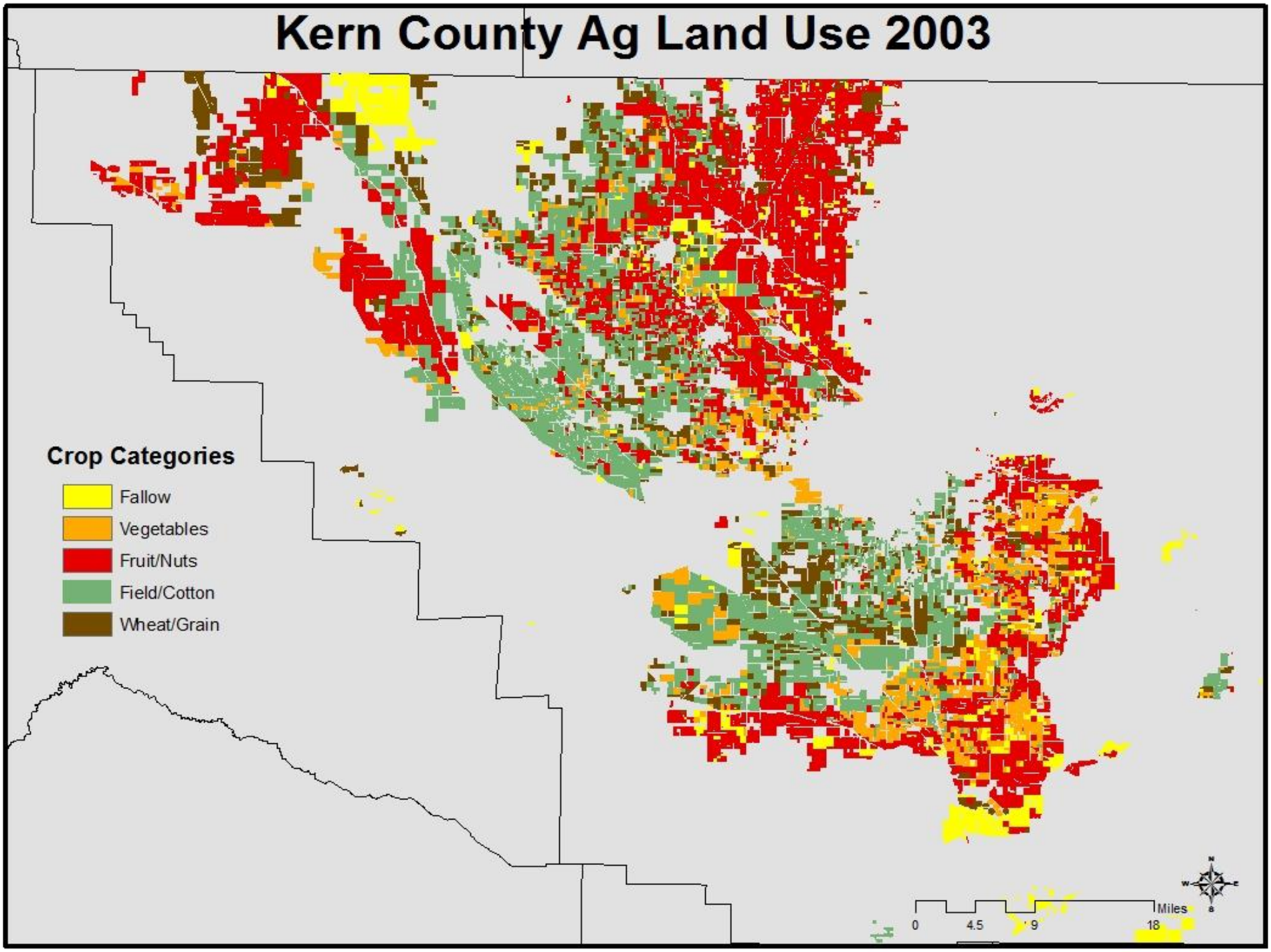

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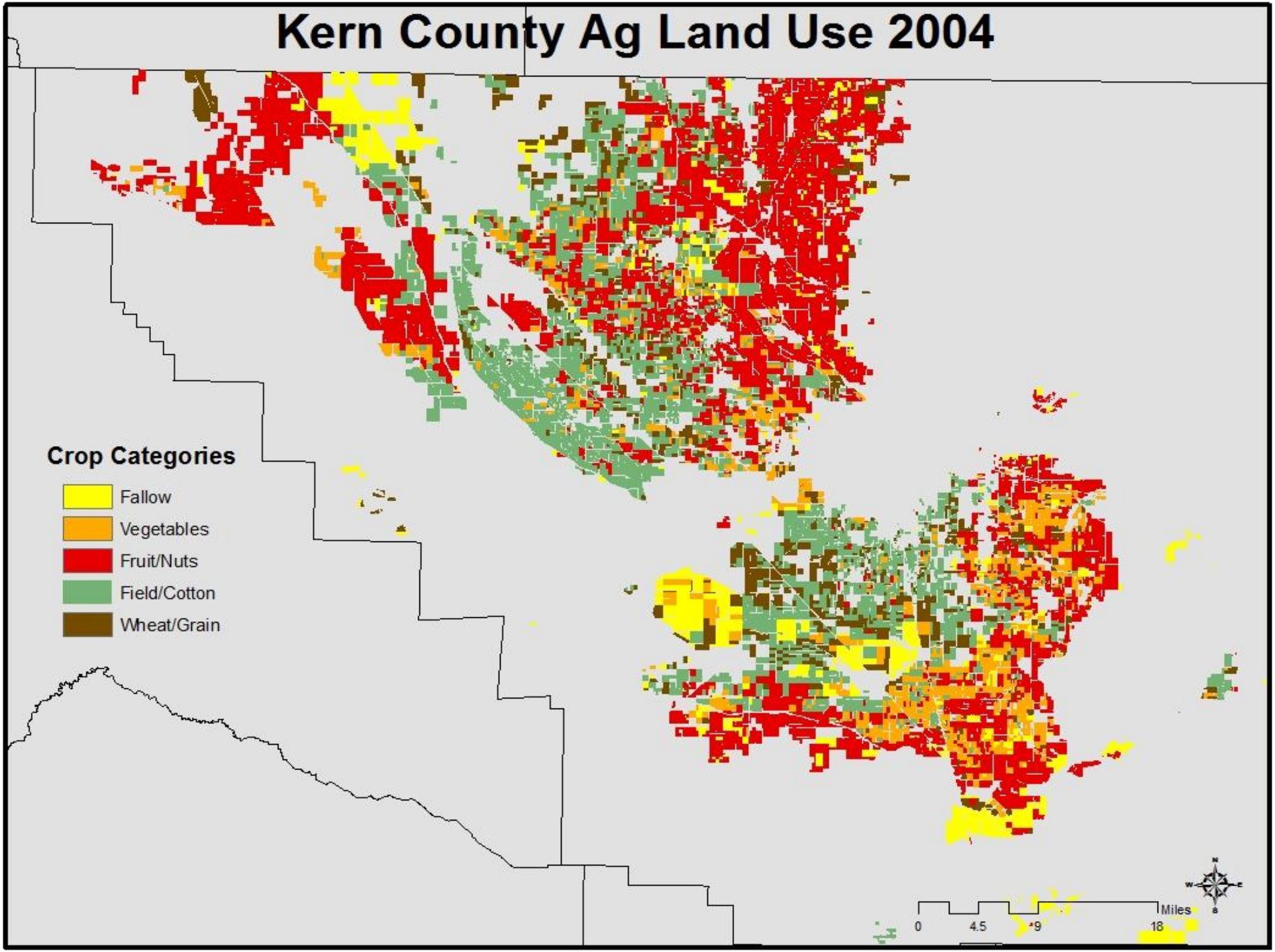

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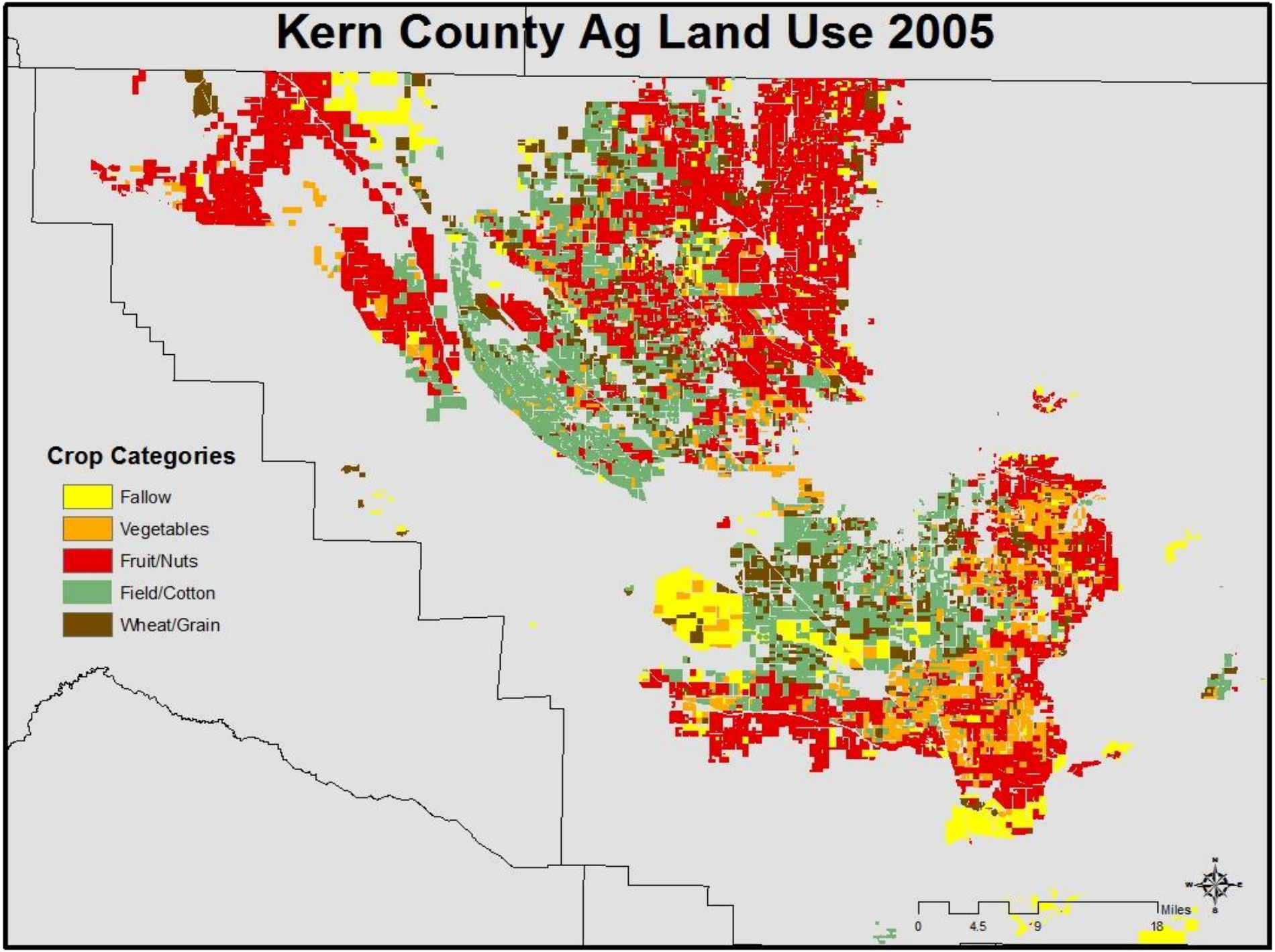

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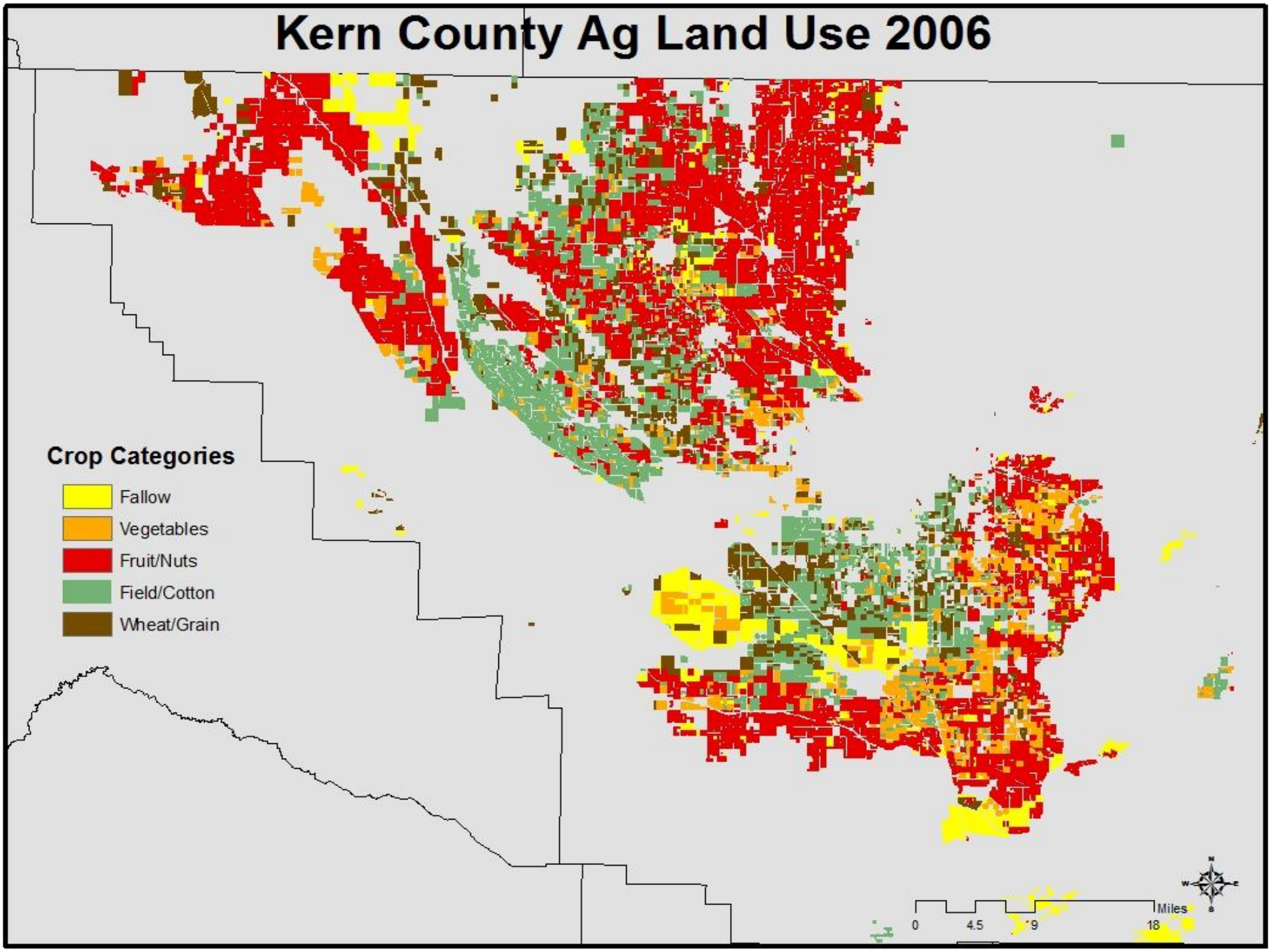

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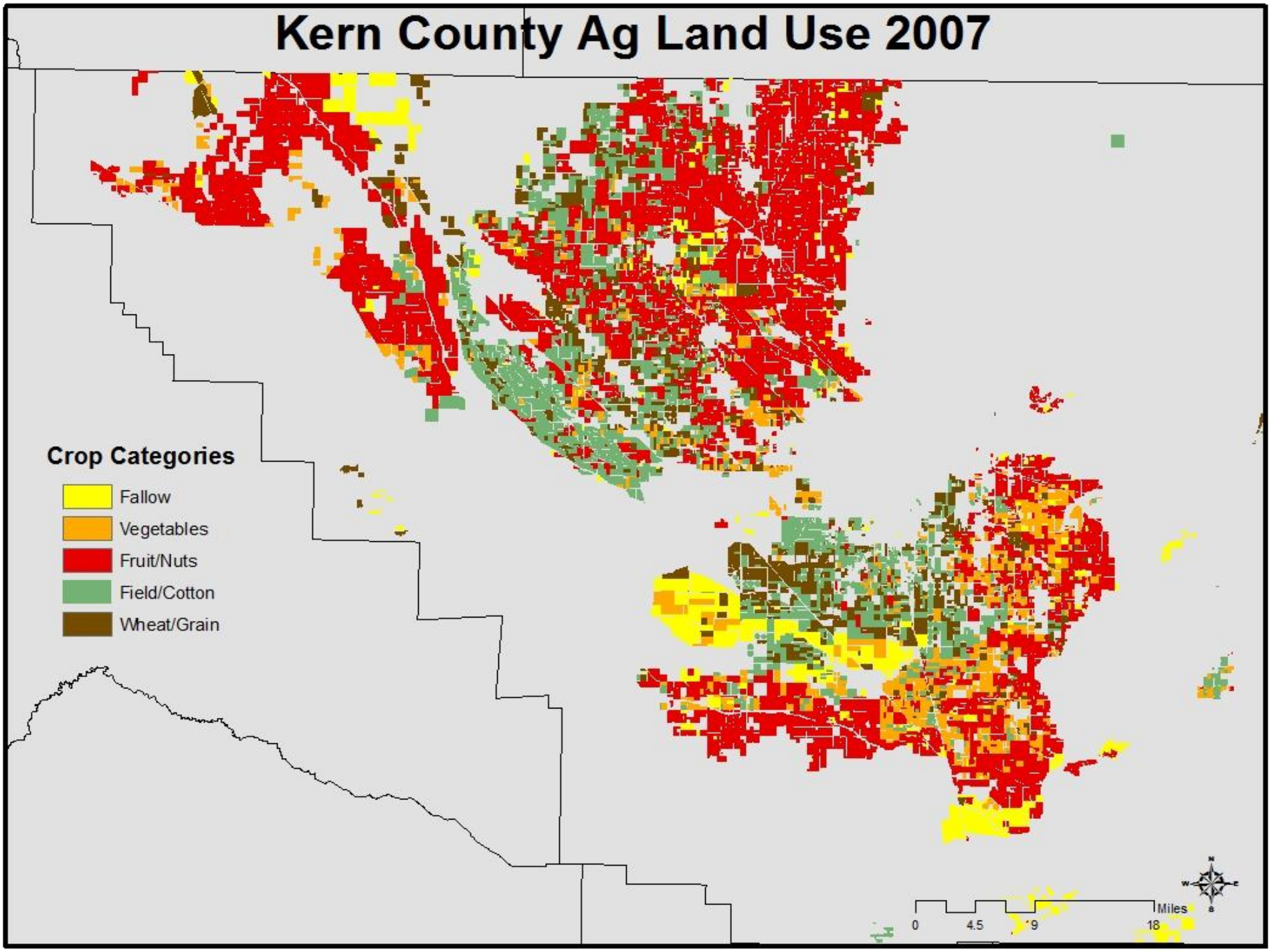

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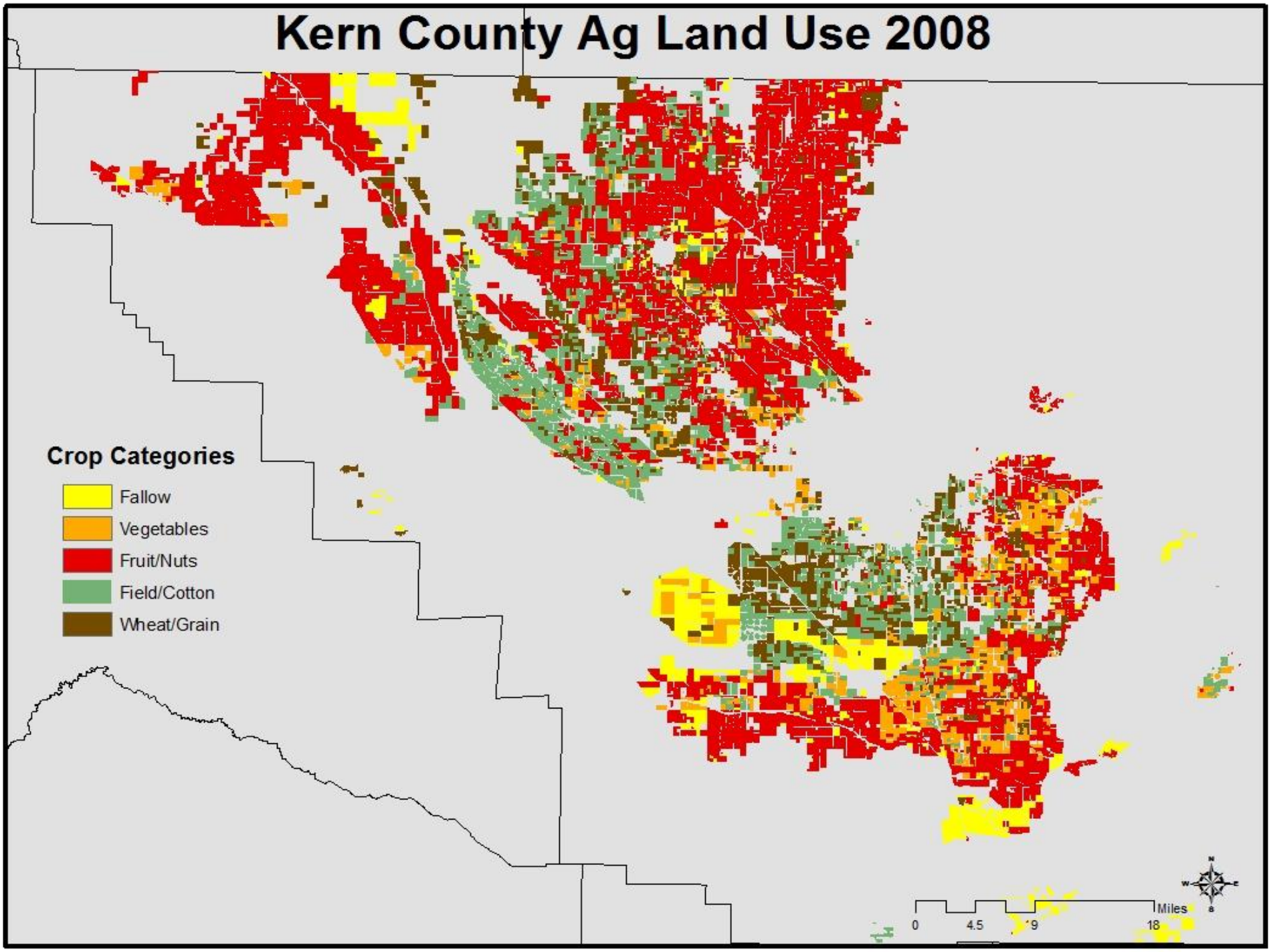

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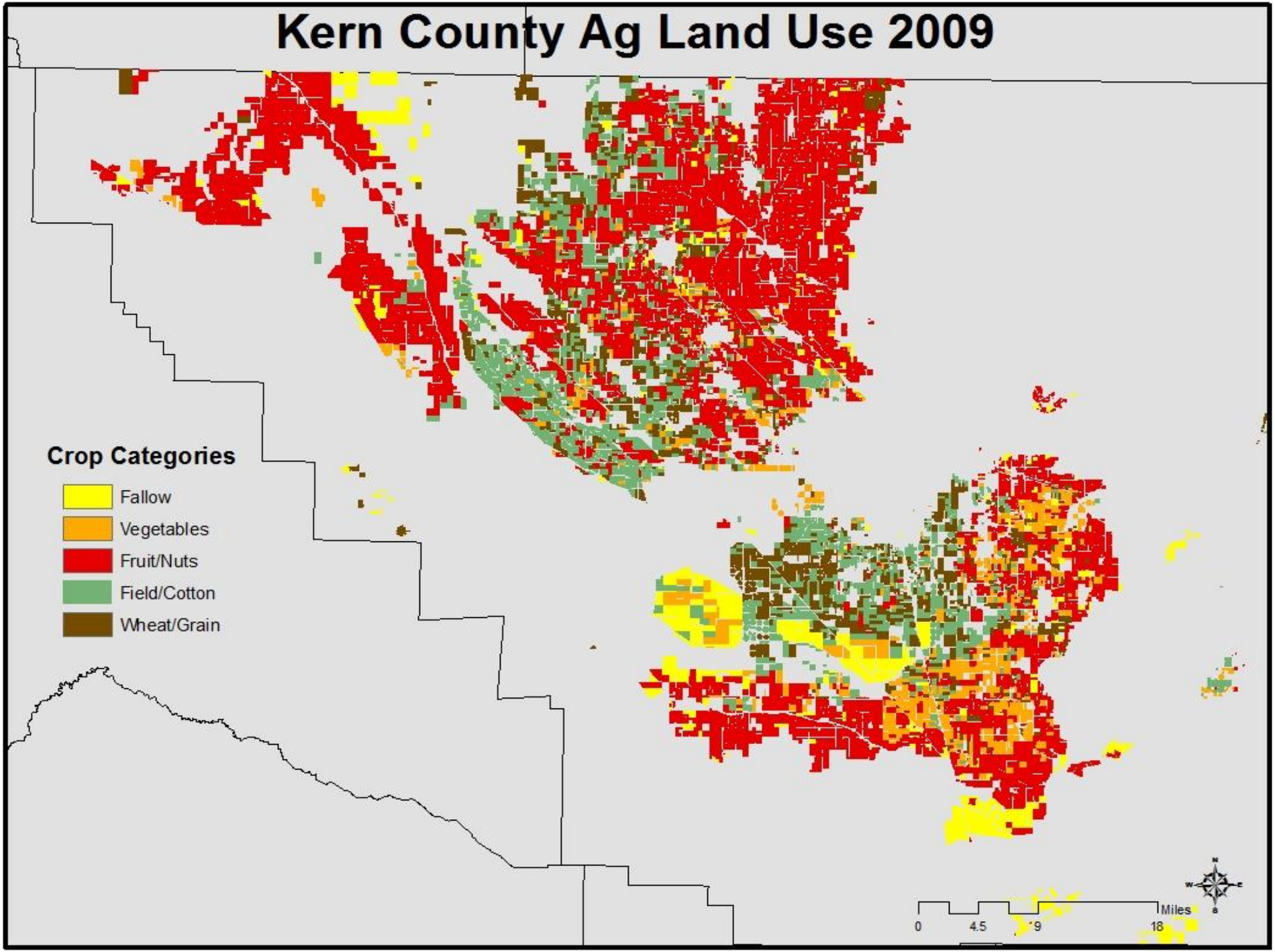

Context and Motivation

- **Existing Literature**
  - **Fixed-proportion rotation constraints**
  - **Econometric specifications**
  - **Aggregate optimal control**
  - **Multi-phase dynamic systems**

- **Rotations in Sustainable Production**
  - **Measuring dynamic behavior**
  - **Switching costs matter**
  - **Changes in cost will change rotations-How?**

- **Agricultural-environmental Policies**
  - **Fields matter, location & timing**

Field Data

- **Kern County 1997-2009**
  - **Crop grown and double cropping at the field level**
    - **14,229 fields, 1 million irrigated acres**
  - **Shallow groundwater salinity**
  - **Soil quality (SSURGO)**
  - **Field owner and operator**
  - **Actual ET (30m x 30m)**
  - **Dry biomass (30m x 30m)**

- **Economic and Climate Variables**
  - **Prices, yields**
  - **Water year and rainfall**
  - **Geographic variables**

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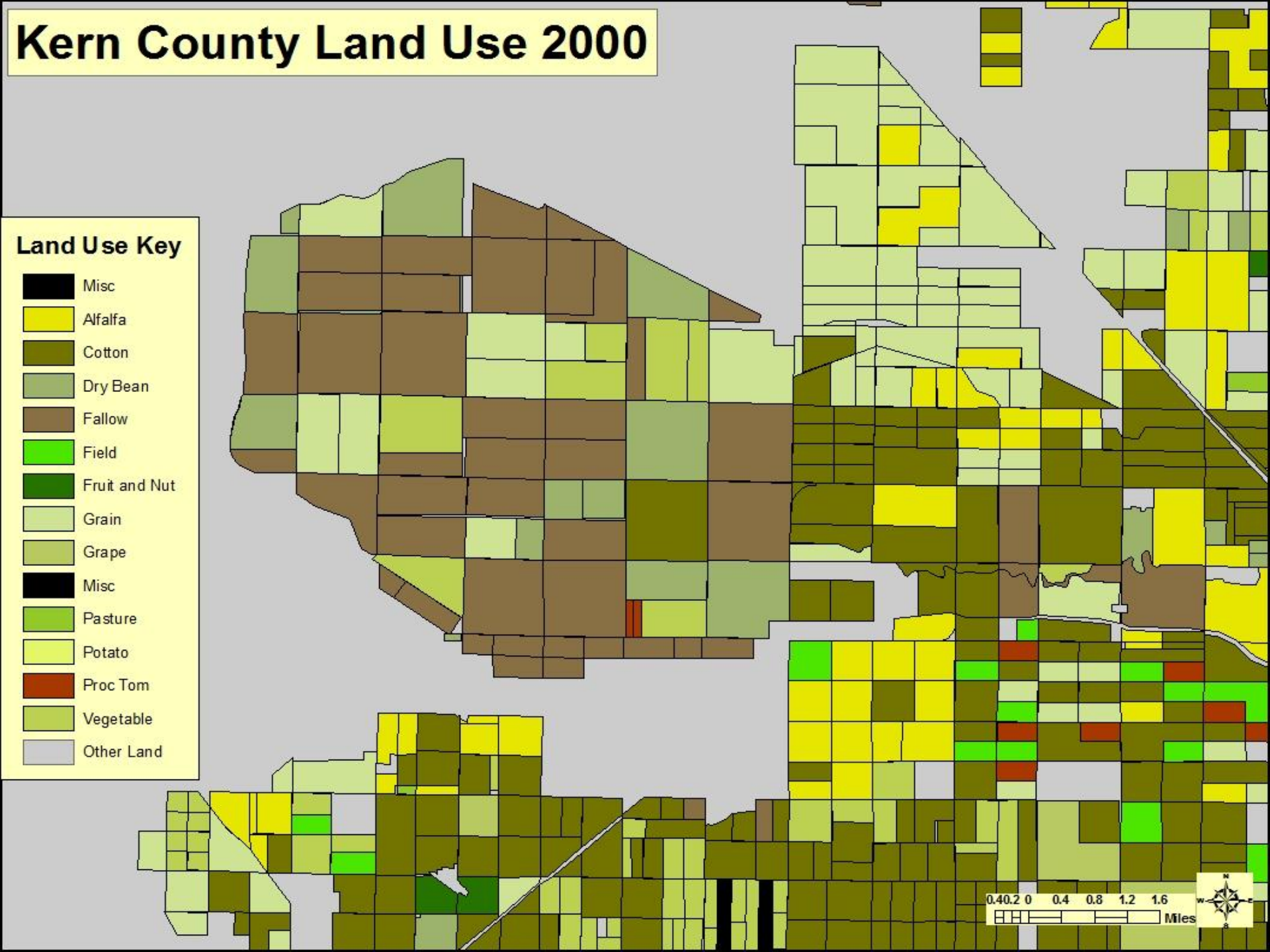

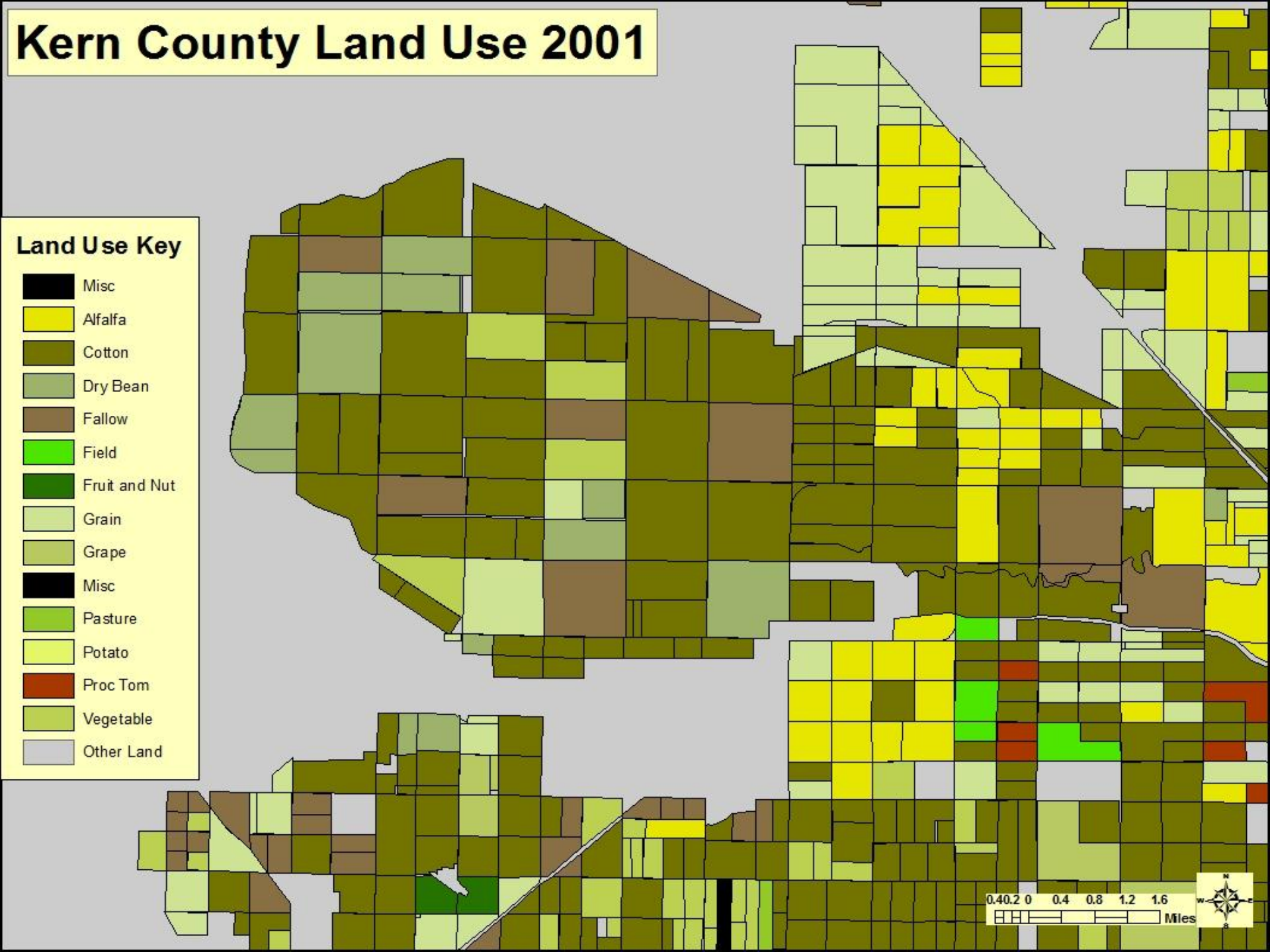
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Land Use Key
Misc
Alfalfa
Cotton
Dry Bean
Fallow
Field
Fruit and Nut
Grain
Grape
Misc
Pasture
Potato
Proc Tom
Vegetable
Other Land
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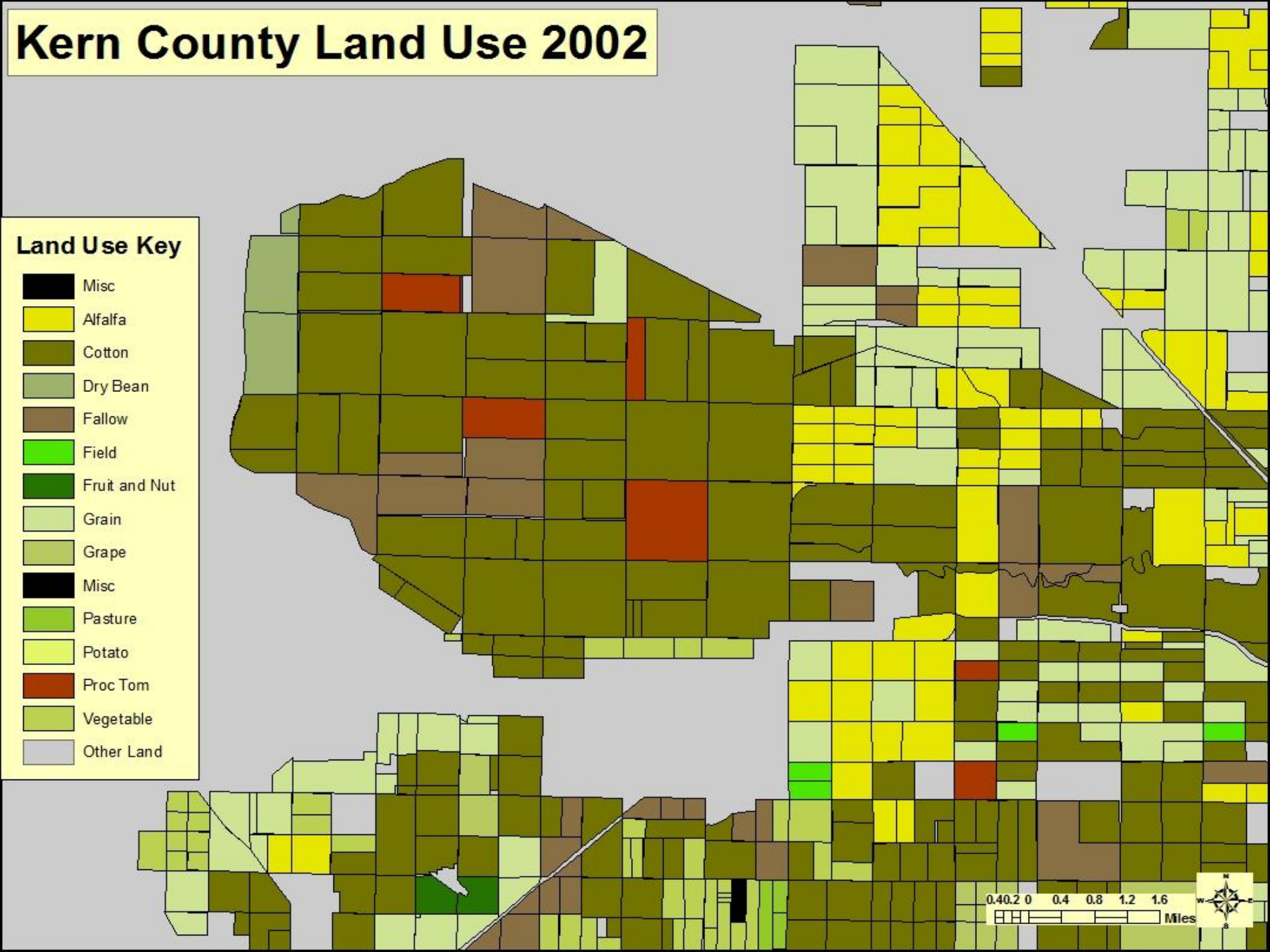

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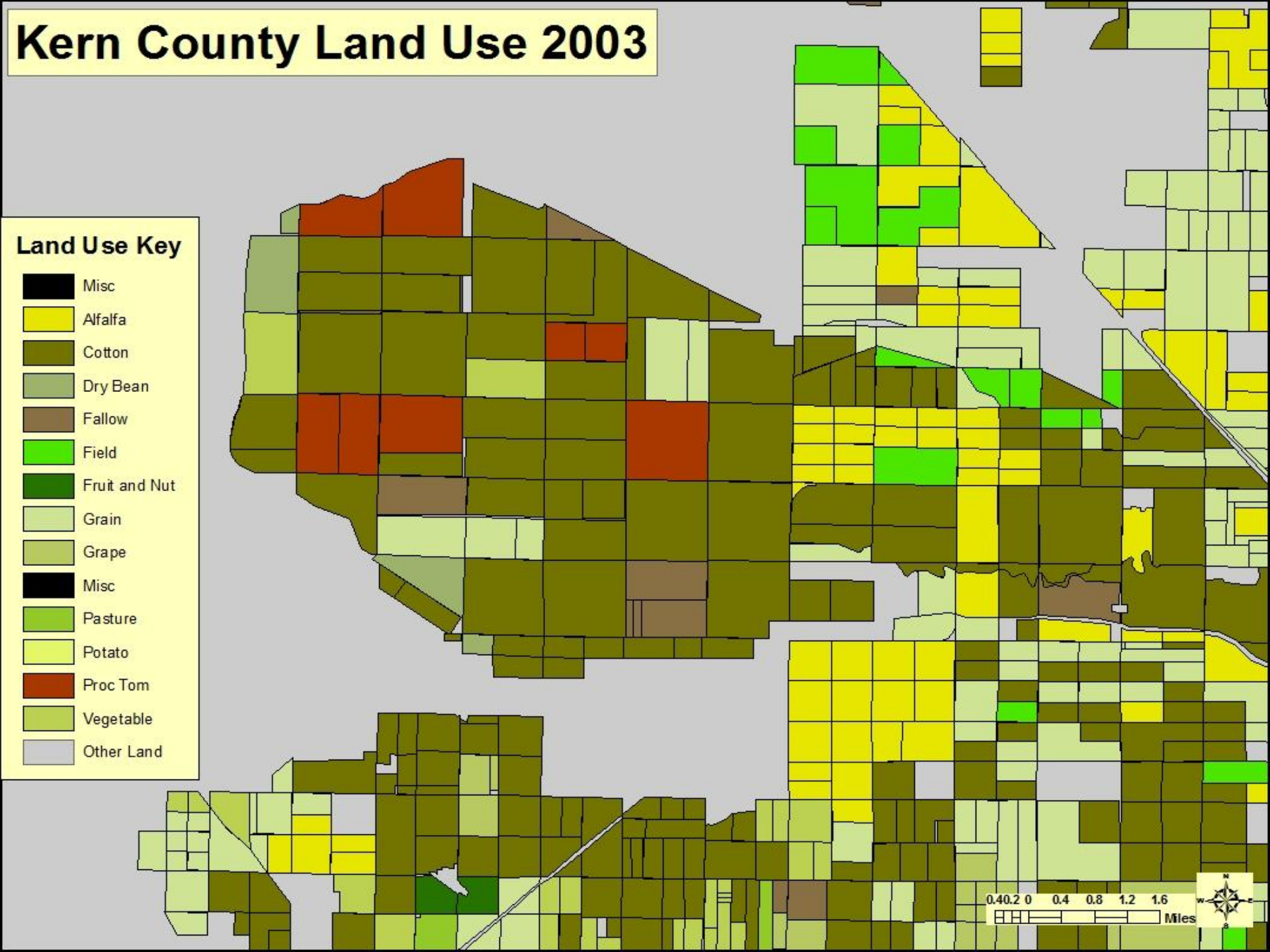

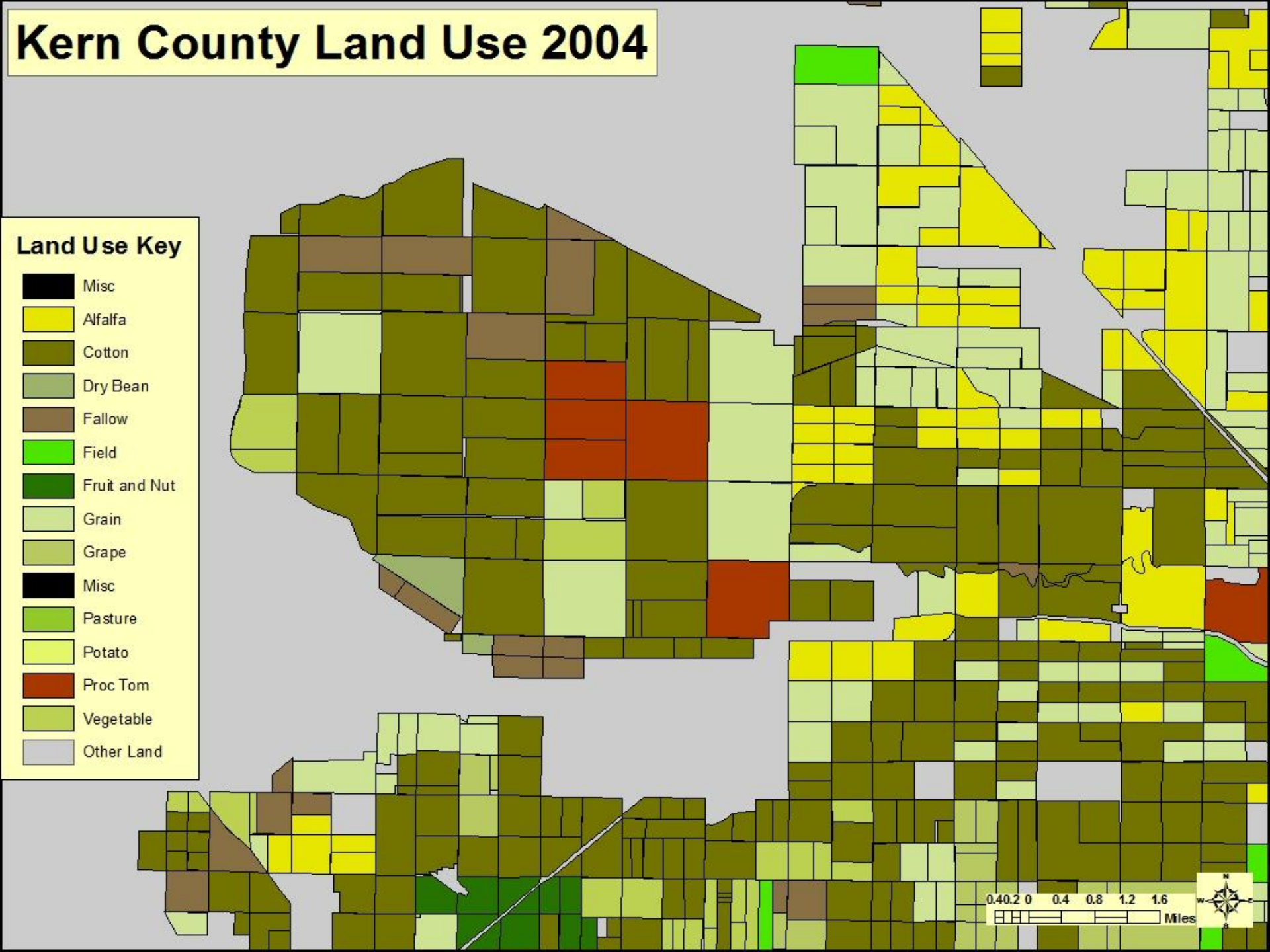
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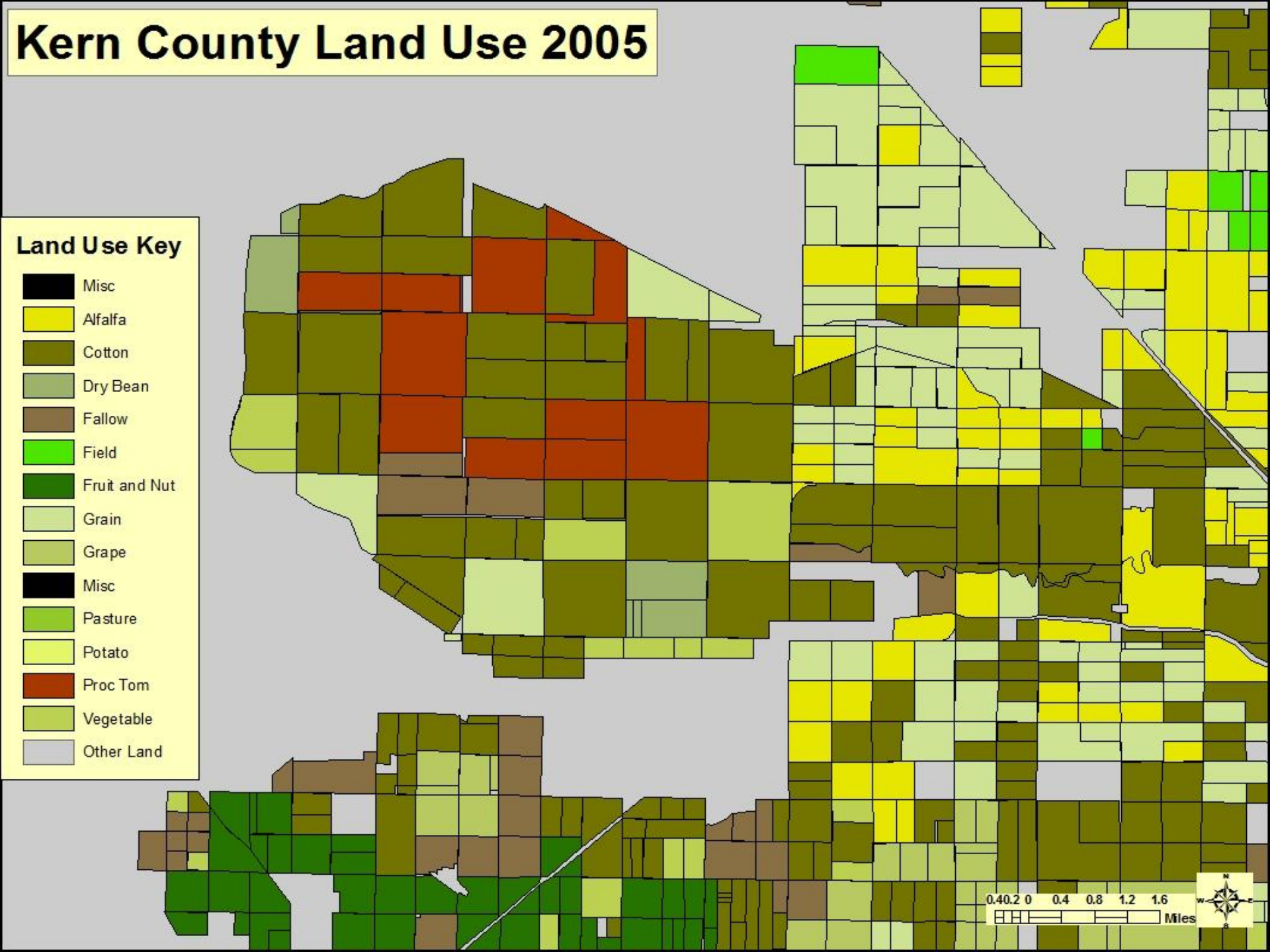

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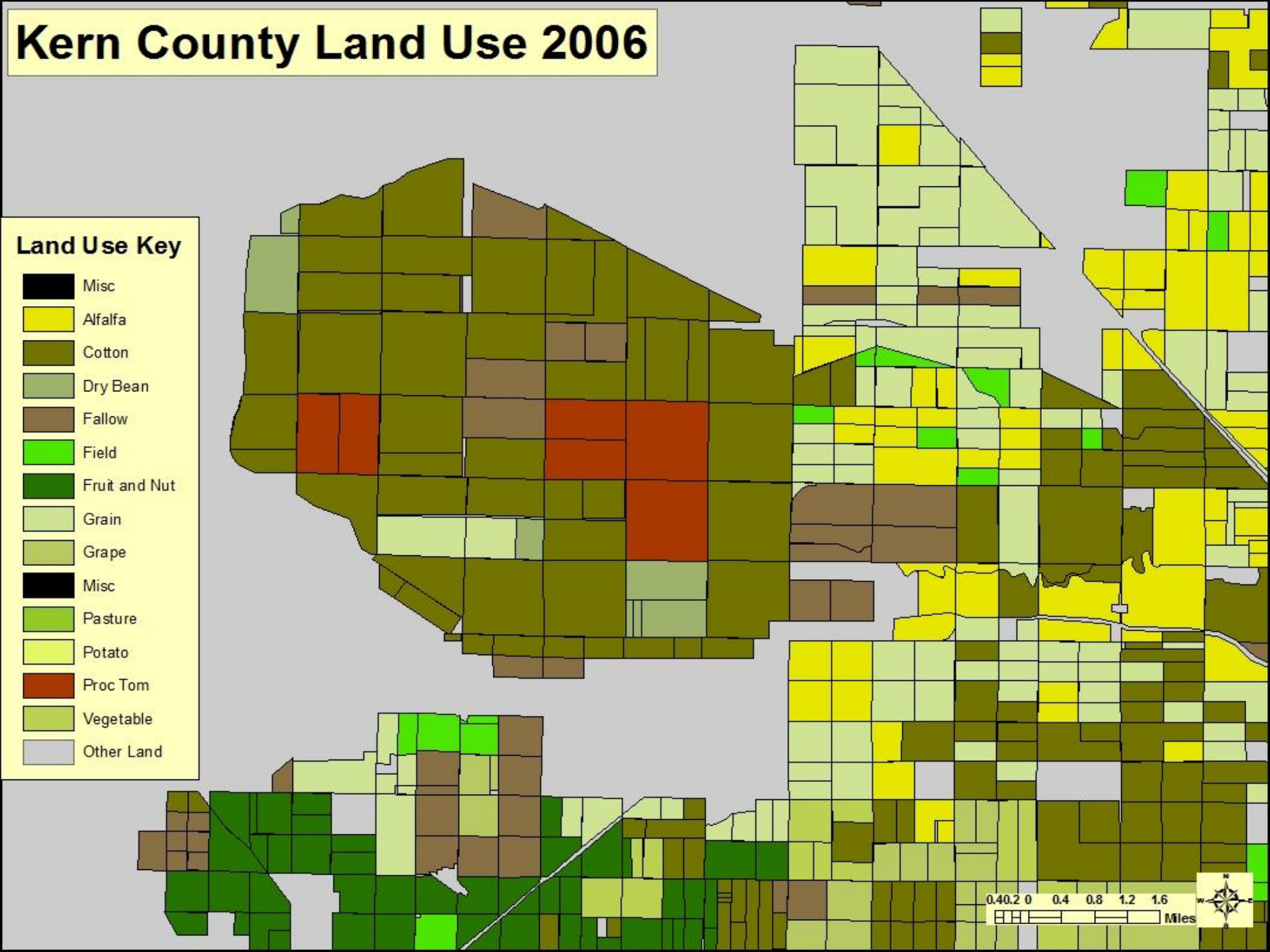

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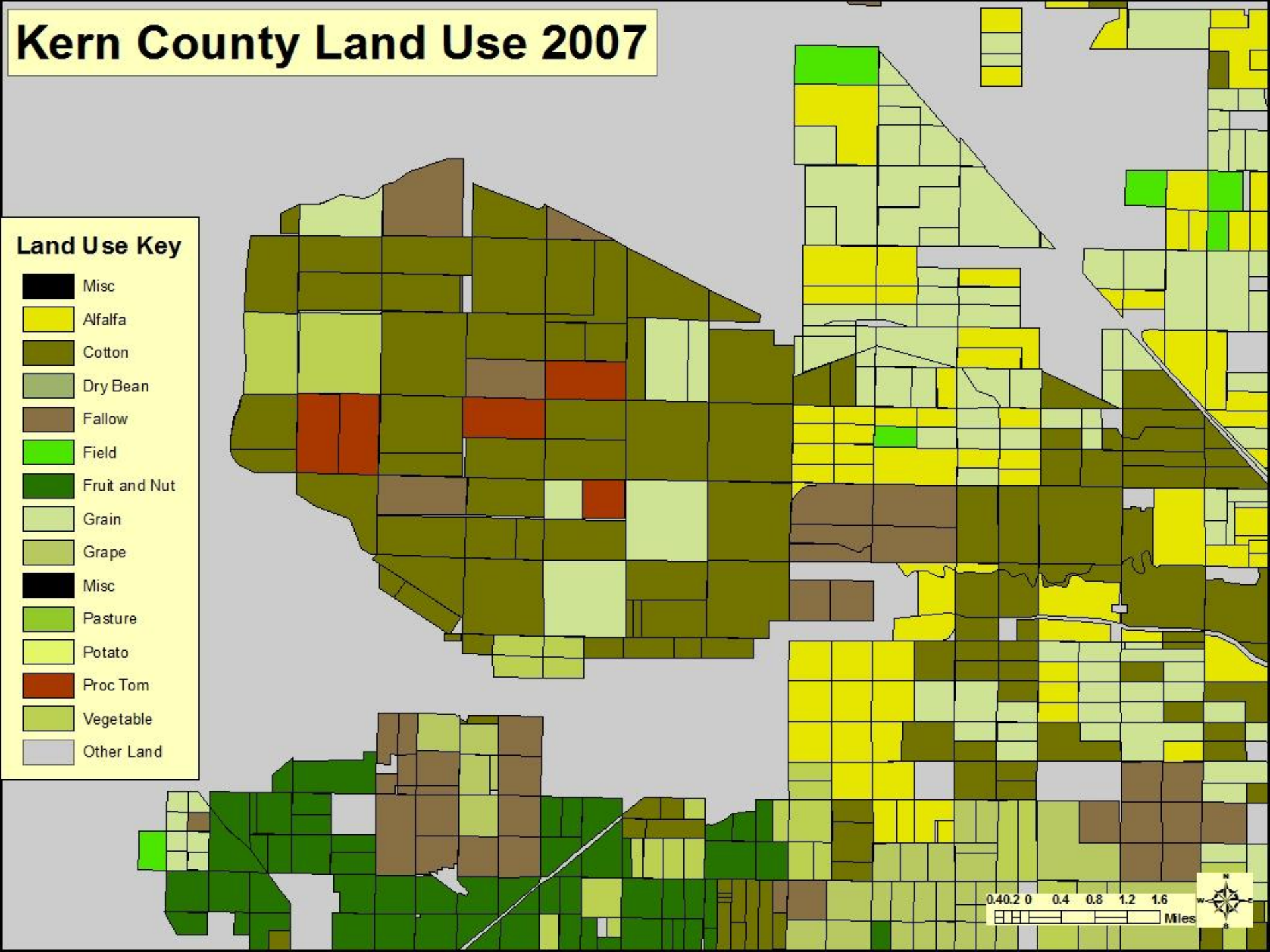

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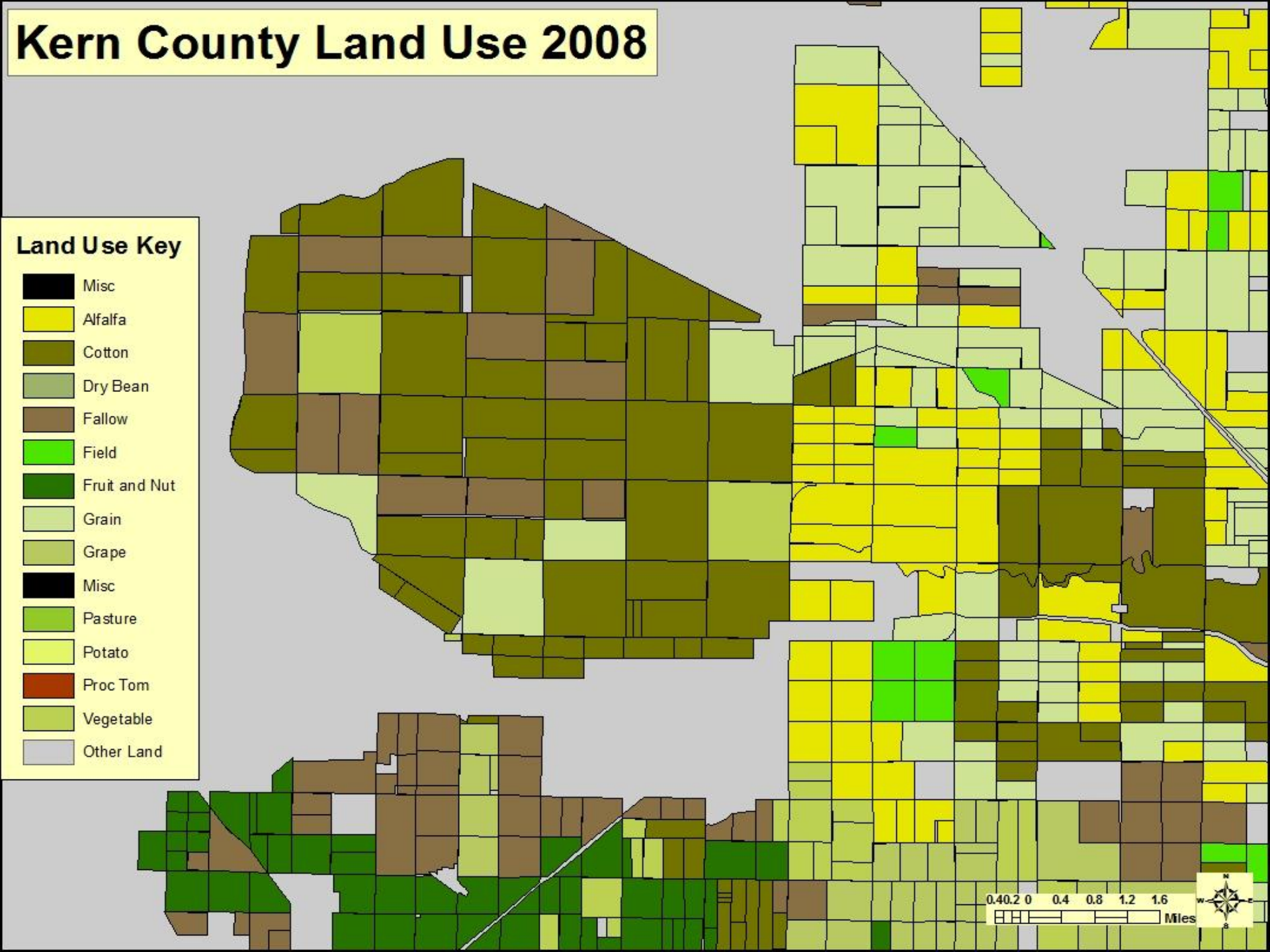

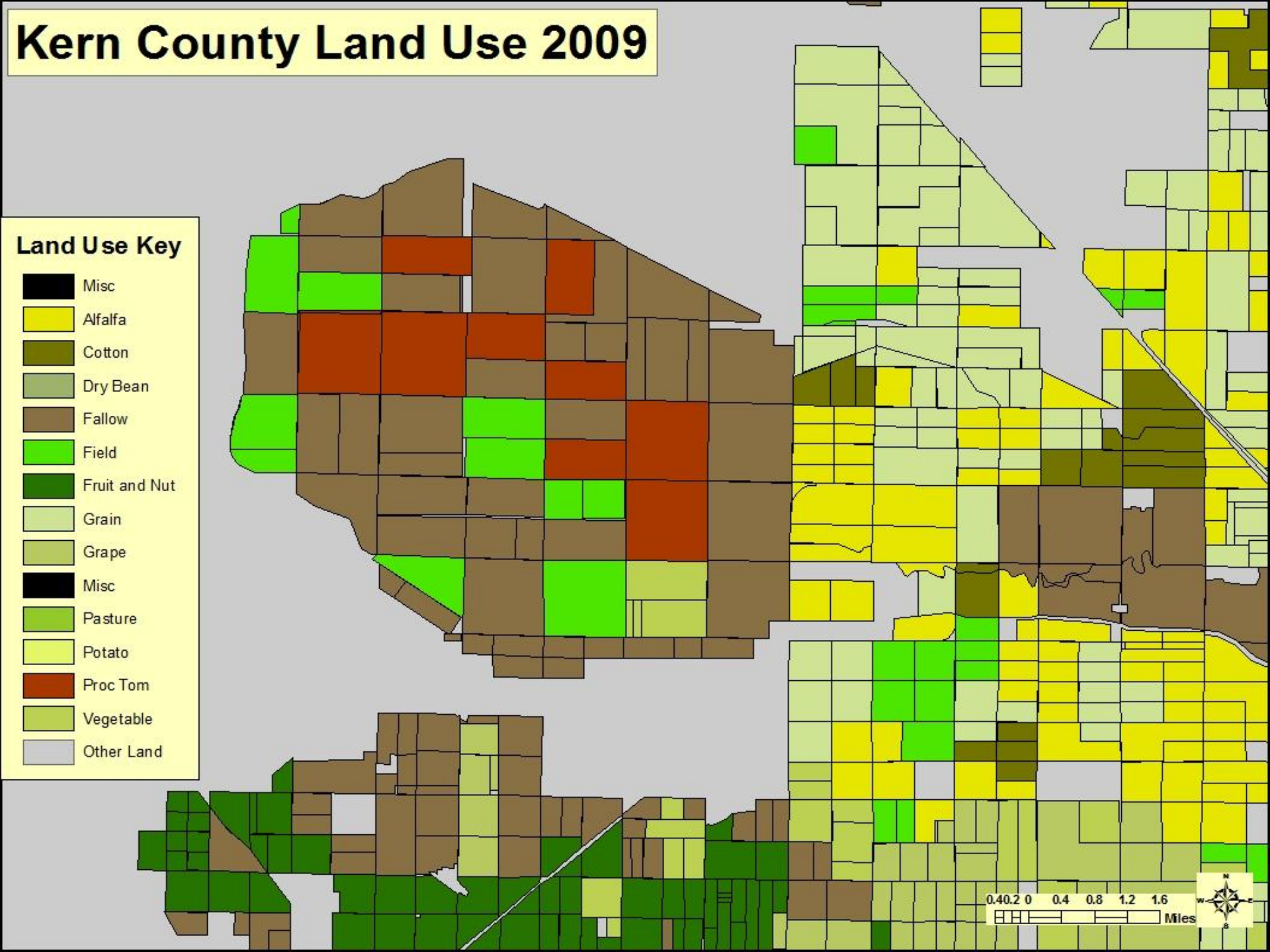
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Identifying Rotations

- **Sequence Alignment**
  - **Needleman & Wuncsh (1970) Journal of Molecular Biology**
  - **Crop sequences and DNA**
    - **Length, embedded sequences**
    - **String editing, language processing, finance**
  - **Optimal Matching Algorithm**
    - **Brzinksy-Fay, Kohler, Luniak (2006)**

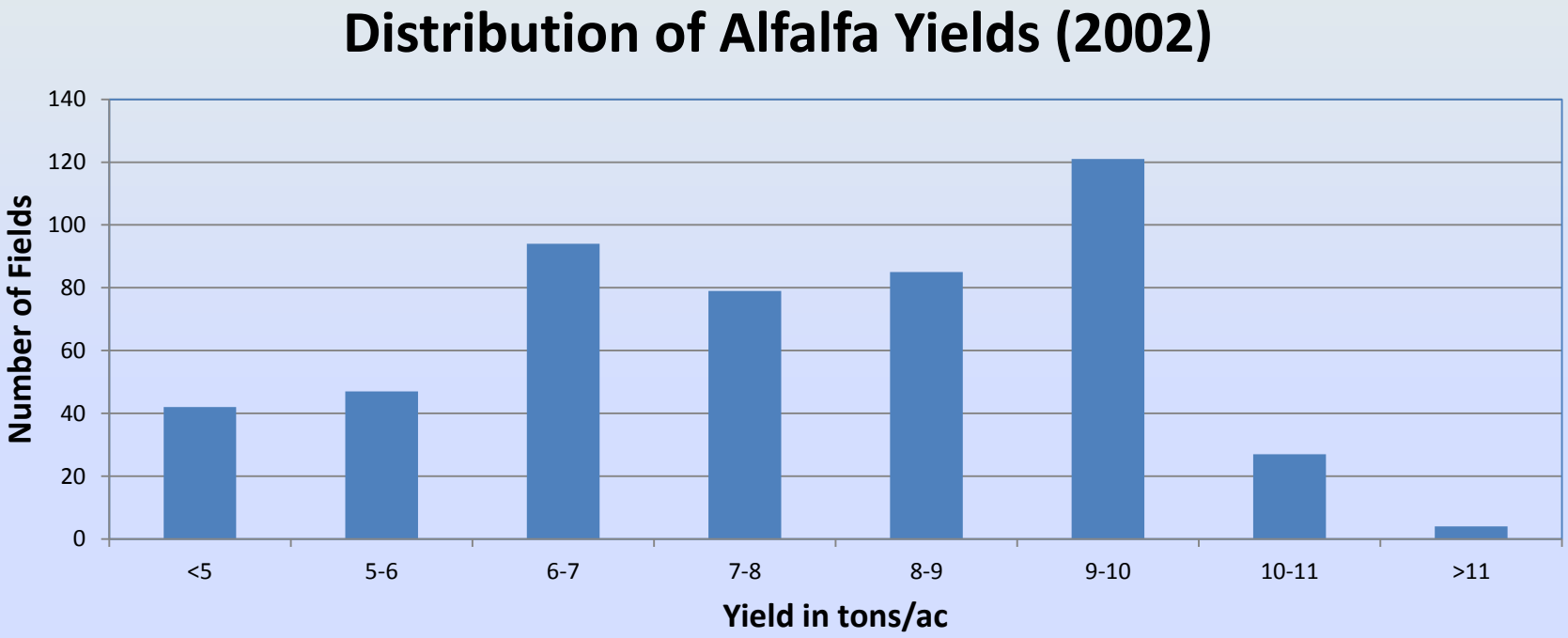
(1) **AAAACGF AAAAG** (2) **ACGF AAAVG AA**

Alfalfa-Cotton-Grain-Fallow

Observed Rotations in Kern County

Rank	Rotation System	Percent of Total	Number of Fields
1	Alfalfa-Cotton-Grain	6.73	534
2	Alfalfa-Grain-Fallow	5.40	429
3	Alfalfa-Grain	4.48	356
4	Alfalfa-Corn-Cotton-Grain	4.45	353
5	Alfalfa-Cotton	3.74	297
6	Multi-year Fallow	2.85	226
7	Fallow-Grain	2.71	215
8	Fallow-Cotton-Grain	2.44	194
9	Grain-Potato-Vegetable	2.41	191
10	Corn-Cotton-Grain	2.29	182

Incorporating Perennial Alfalfa



YR1: 8.1 ton/ac YR2: 8.3 ton/ac YR3: 7.9 ton/ac YR4: 7.4 ton/ac

Parameter Estimates

- **Marginal reduction in mean yield from 1 unit change in salt/soil**

(tons/ac)	1 dS/m Increase
Crop	**Salinity Parameter**
Alfalfa	-0.675
Cotton	-0.058
Grain	-0.230
Fallow	-

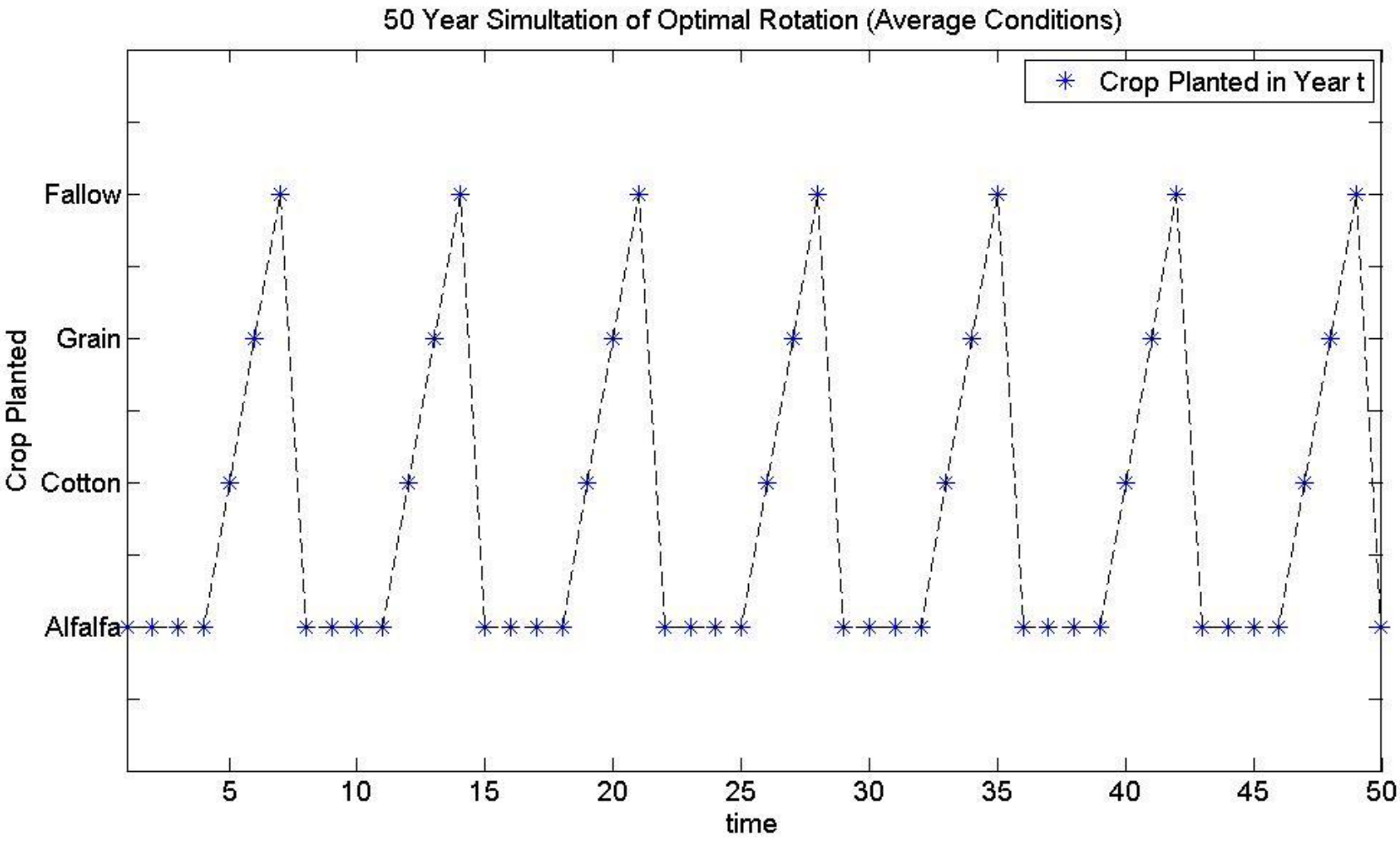
(tons/ac)	1 “unit” Decrease
Crop	**Soil Parameter**
Alfalfa	-0.119
Cotton	-0.012
Grain	-0.039
Fallow	-

Parameter Estimates

Yield (%)	Marginal percentage change in mean yield given (row) follows (column)						
next\last	ALF1	ALF2	ALF3	ALF4	COT	GRN	FAL
ALF1	-11.05	-13.48	-14.24	-8.82	-14.70	-7.55	**19.35**
ALF2	**12.34**	-	-	-	-	-	-
ALF3	-	**16.15**	-	-	-	-	-
ALF4	-	-	**17.39**	-	-	-	-
COT	-11.25	-18.02	-20.07	**13.97**	-20.12	-49.57	-19.03
GRN	-8.20	-8.20	-8.20	-8.20	**21.29**	-40.14	-8.96
FAL	-	-	-	-	-	-	-

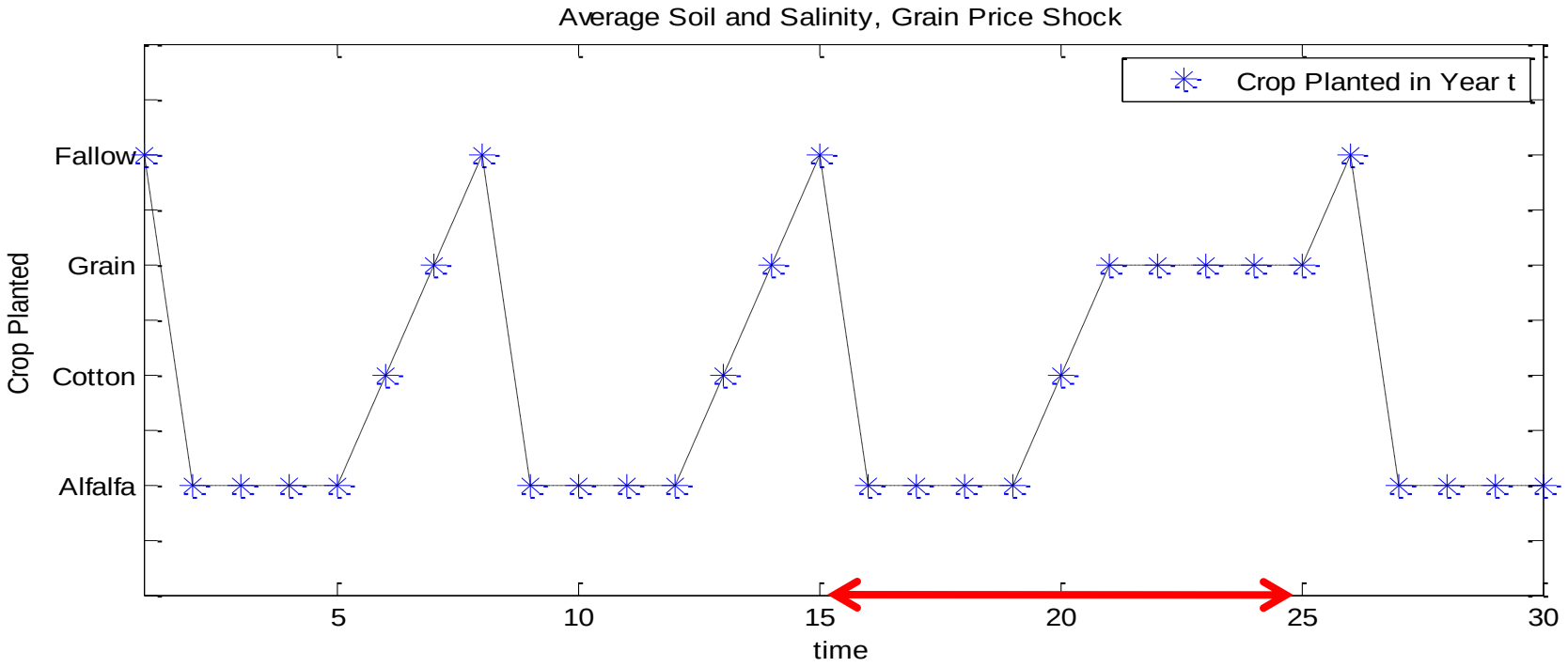
Cost (%)	Marginal percentage change in average costs given (row) follows (column)						
next\last	ALF1	ALF2	ALF3	ALF4	COT	GRN	FAL
ALF1	12.07	12.78	13.38	11.70	18.71	11.50	**-14.31**
ALF2	**-13.34**	-	-	-	-	-	-
ALF3	-	**-15.39**	-	-	-	-	-
ALF4	-	-	**-17.66**	-	-	-	-
COT	11.71	13.85	17.60	**-13.22**	20.94	21.68	14.64
GRN	11.50	11.50	11.50	11.50	**-20.01**	21.50	11.95
FAL	11.50	11.50	11.50	11.50	11.50	**-100.00**	11.50

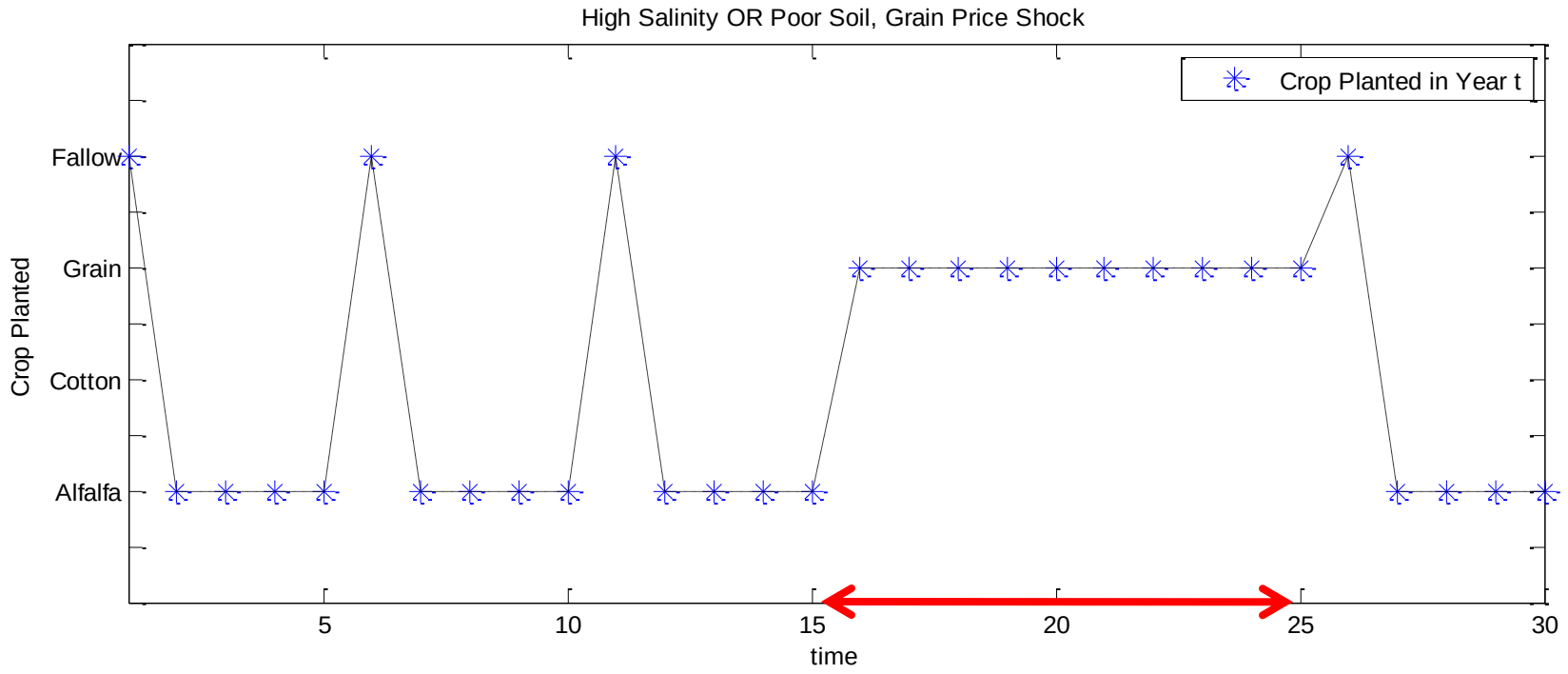
Base Model Results



Grain Price Shock

- **Example: Grain price shock ($100 per ton) in year 15, lasting 10 years.**




High Salinity OR Poor Soil, Grain Price Shock
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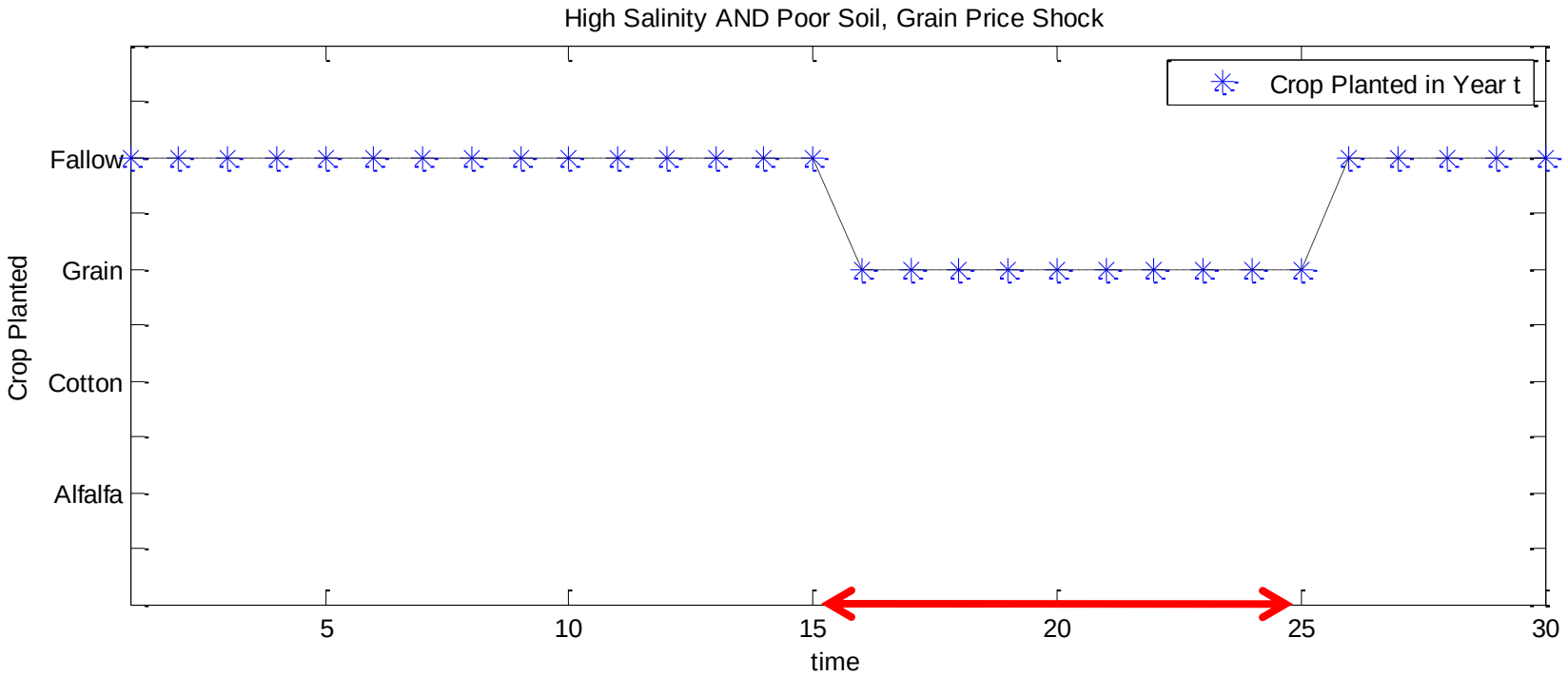
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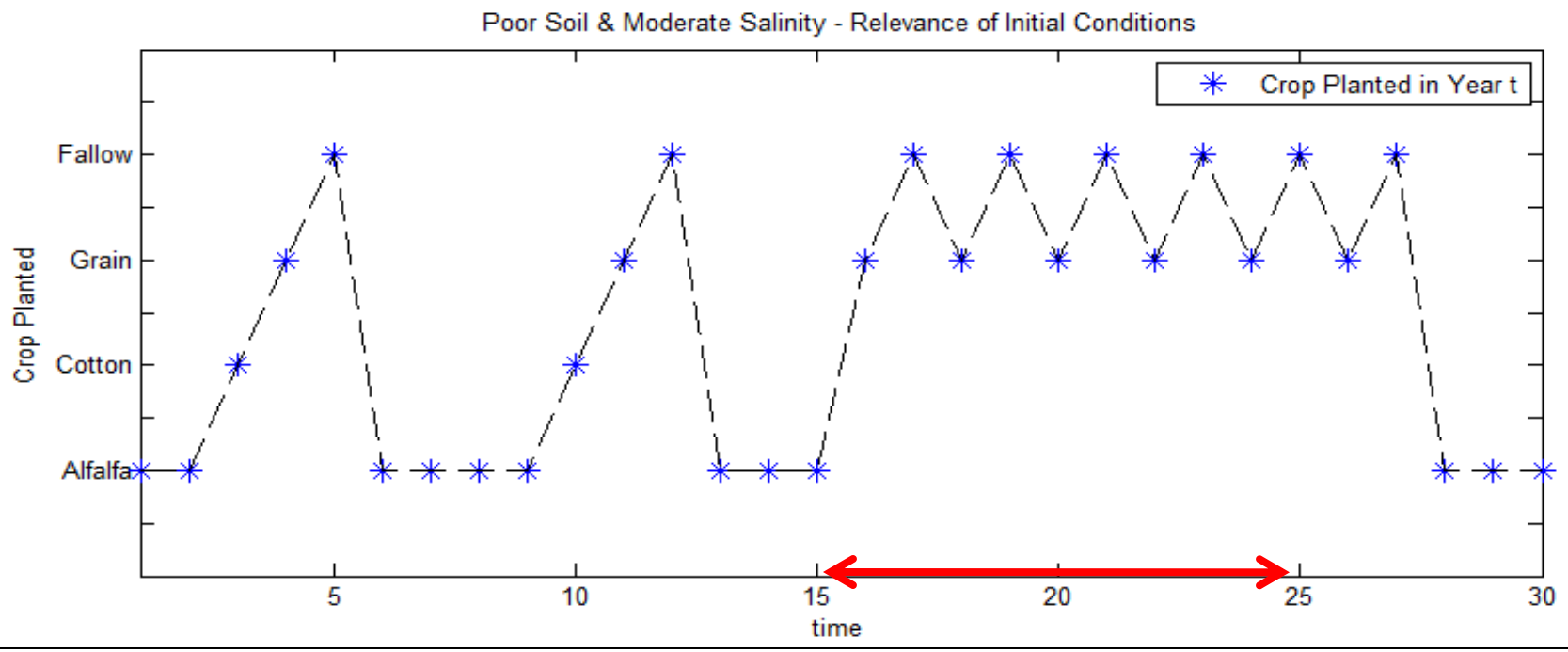
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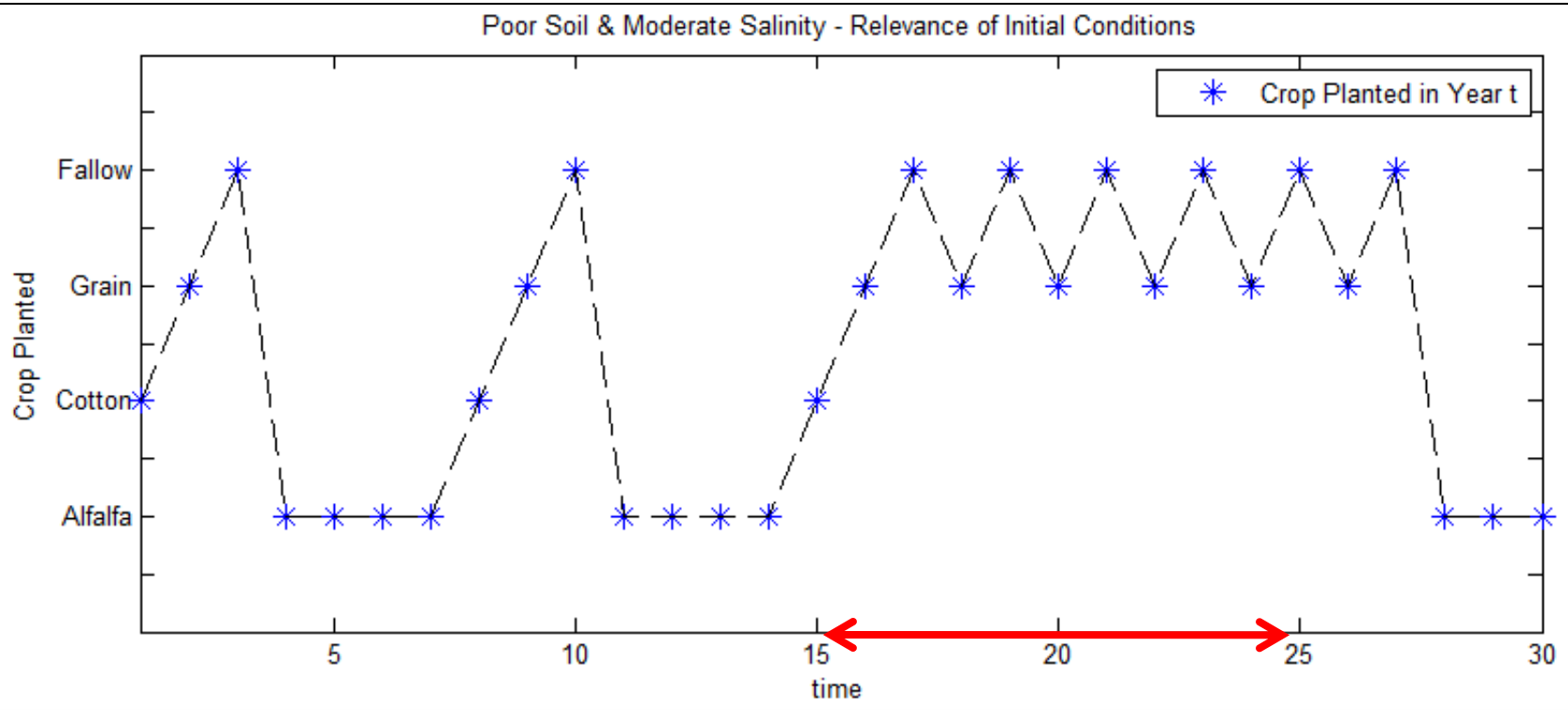
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Summary and Conclusion

- **Dynamic Programming Model of Crop Rotation**
  - **Identify empirical rotations**
  - **Define dynamic model to reproduce rotations**
  - **Estimate parameters implied by farmer behavior**
  - **Solve and simulate the dynamic model**

- **Motivation**
  - **Measuring the Rotational response to sustainable policies**
  - **Spatially dependent environmental policies**

- **Extensions**
  - **Include explicit input use- nitrogen**
  - **Orchard crop investment- Hurdle rate**
  - **Underlying dynamics: pests, disease, fertility**
  - **Implications for traditional production models**