# Terrestrial Acidification, Ecotoxicity, and Eutrophication Potential Are Reduced in Production Systems that Include Perennial Forages

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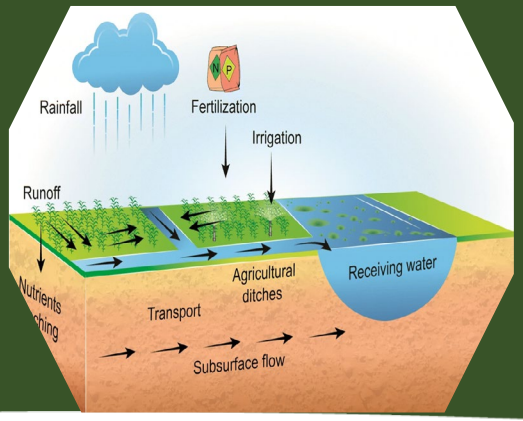
# Introduction


Global agricultural challenges:

climate change, biodiversity loss, resource depletion

**Modern agriculture:** increased food production but significant environmental impacts

Agriculture responsible for 23% of global anthropogenic GHG emissions

Need for sustainable agricultural practices

(IPCC, 2019)

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# Perennial vs. Annual Forage Systems

## Annual Forages

- Higher soil disturbance and carbon footprint
- Vulnerable to extreme weather events
- Reduce water and air quality and biodiversity

## Perennial Forages


Produce more from the same area of land while reducing negative environmental impacts, conserving natural resources, and enhancing healthy ecosystem services (FAO)

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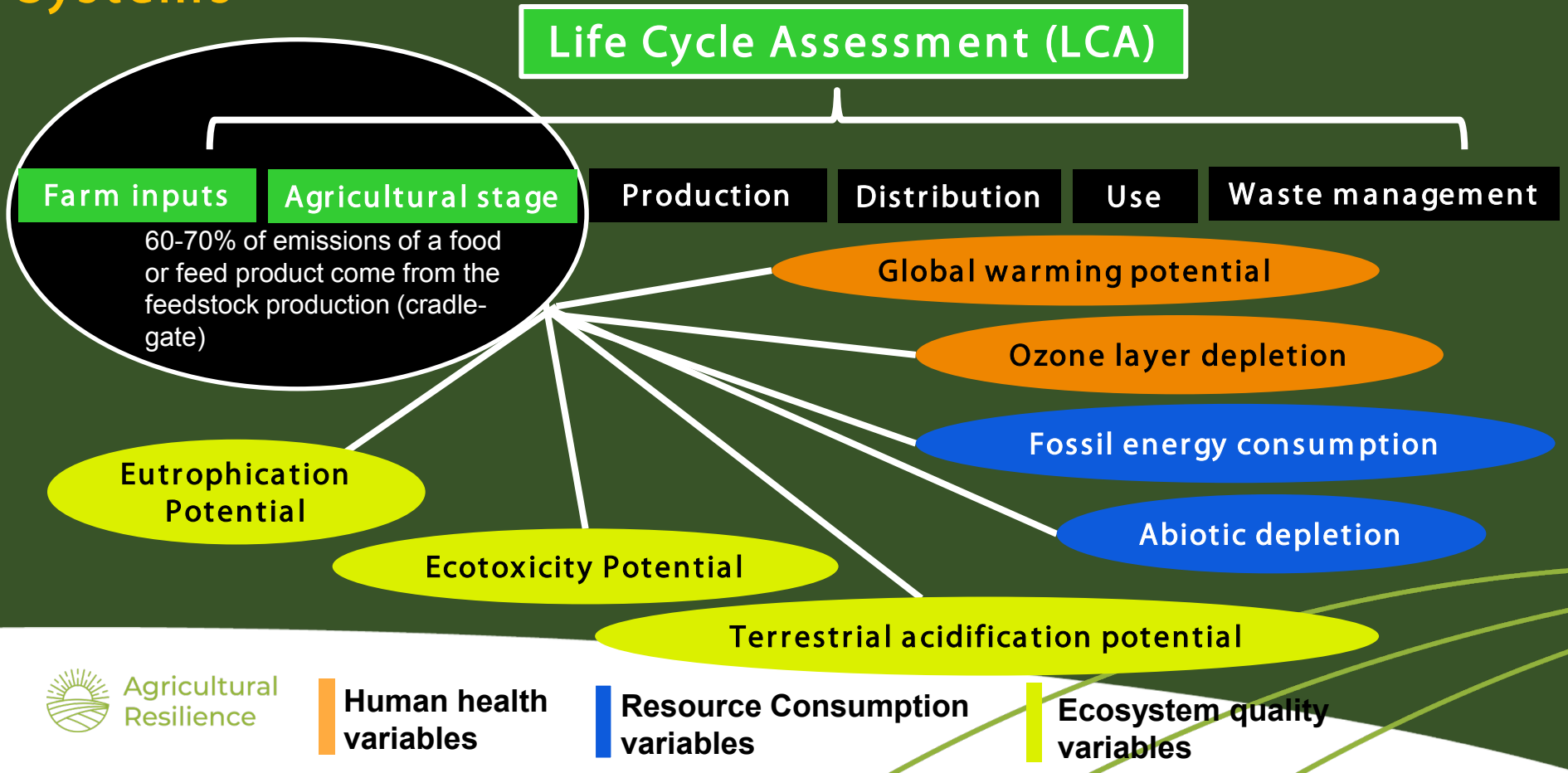
# Environmental Impact Assessment in Forage Production Systems



# Environmental Impact Categories and Emission Concerns

| Environmental Impact categories | Emission concerns | Units |
|---|---|---|
| Global warming potential | $CO_2$, $CH_4$, and $N_2O$ | Mg $CO_2 - eq$ |
| Ozone layer depletion | $CH_3BR$, $Cl$, and $Br$ | $mg\ CFC11\ eq$ |
| Fossil energy consumption | $CO_2$, $CH_4$, $N_2O$, $SO_2$, $NO_x$, and $PM$ | $MJ$ |
| Abiotic depletion | *Minerals and Material Consumption* | $N/A$ |
| Terrestrial acidification | $SO_2$, $NO_x$, and $NH_3$ | $g\ SO_2 - eq$ |
| Ecotoxicity potential | $SO_2$, $NO_x$ etc. | $CTU$ |
| Eutrophication potential | $NO_2^-$, $NO_3^-$, $NO_x$, $NH_3$, and $PO_4^{3-}$ | $kgPO_4^- - eq$ |

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# Research Problem

A comparison of perennial and annual forage cropping systems across environmental impact categories is needed.


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# Research Objectives

- Conduct a system review.
- Novel classification of forage cropping system types:
  **BAU** (business as usual), **BAU-improved**, **AS** (alternative or aspirational system), and **DPCS** (diverse perennial circular system).
- Conduct a meta-analysis.
- Evaluate and compare environmental impacts across moderators:

  **(Number of years with perennials in crop rotation,**

  **Diversification, Crop life cycle, and Cropping system type).**

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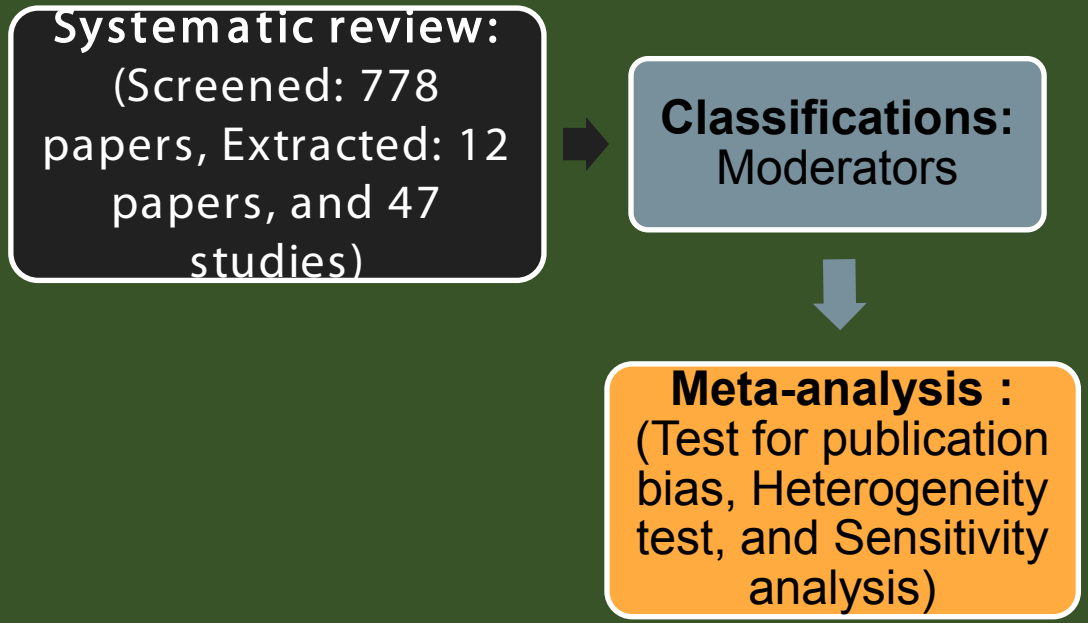
# Meta-Analysis Methodology

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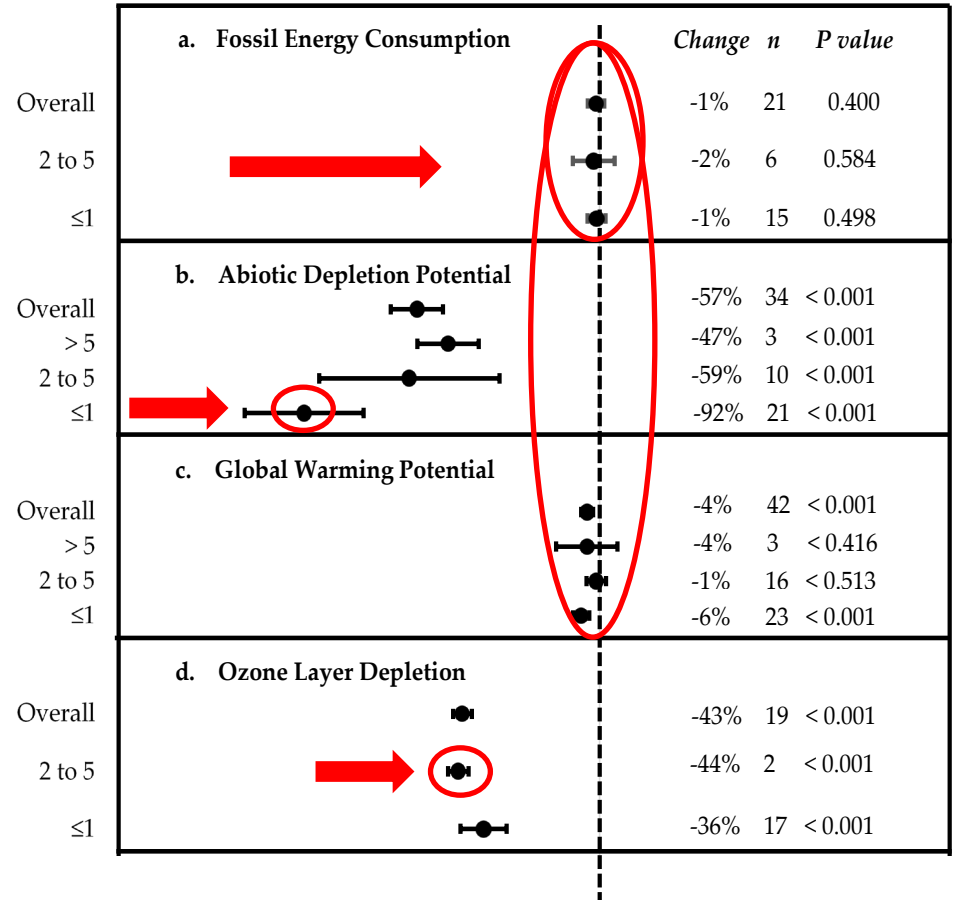
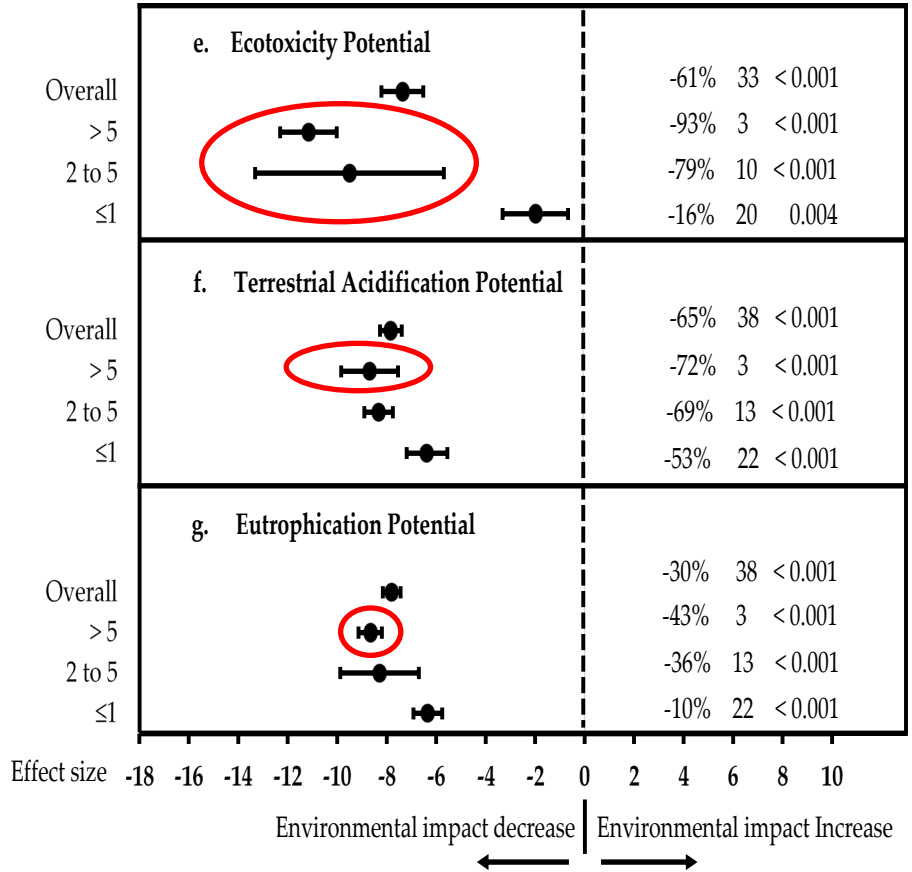
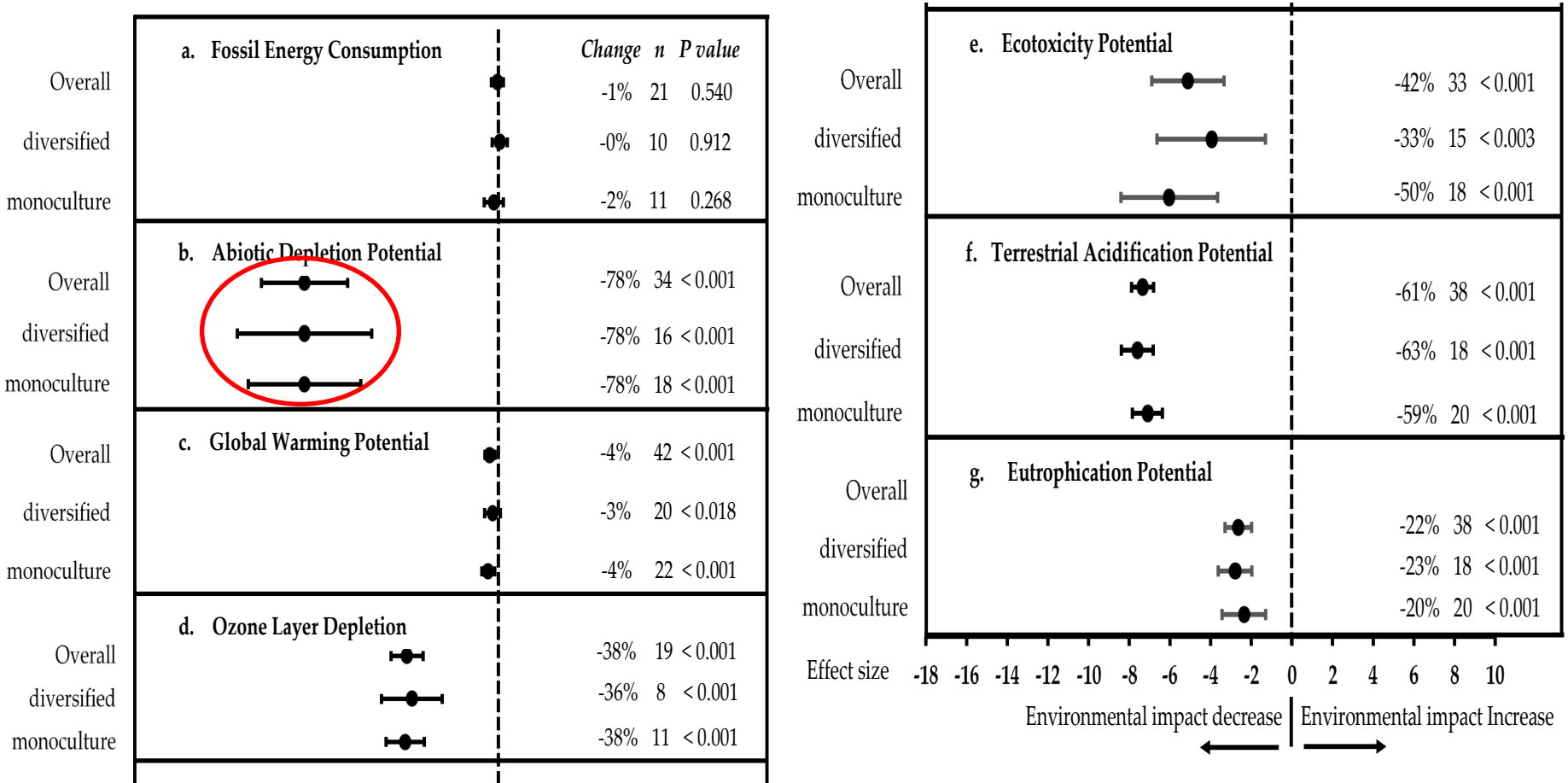
- **Result:** 2-3 years and > 5 years with perennials perform better in reducing ozone layer depletion, ecotoxicity, terrestrial acidification, and eutrophication potential.

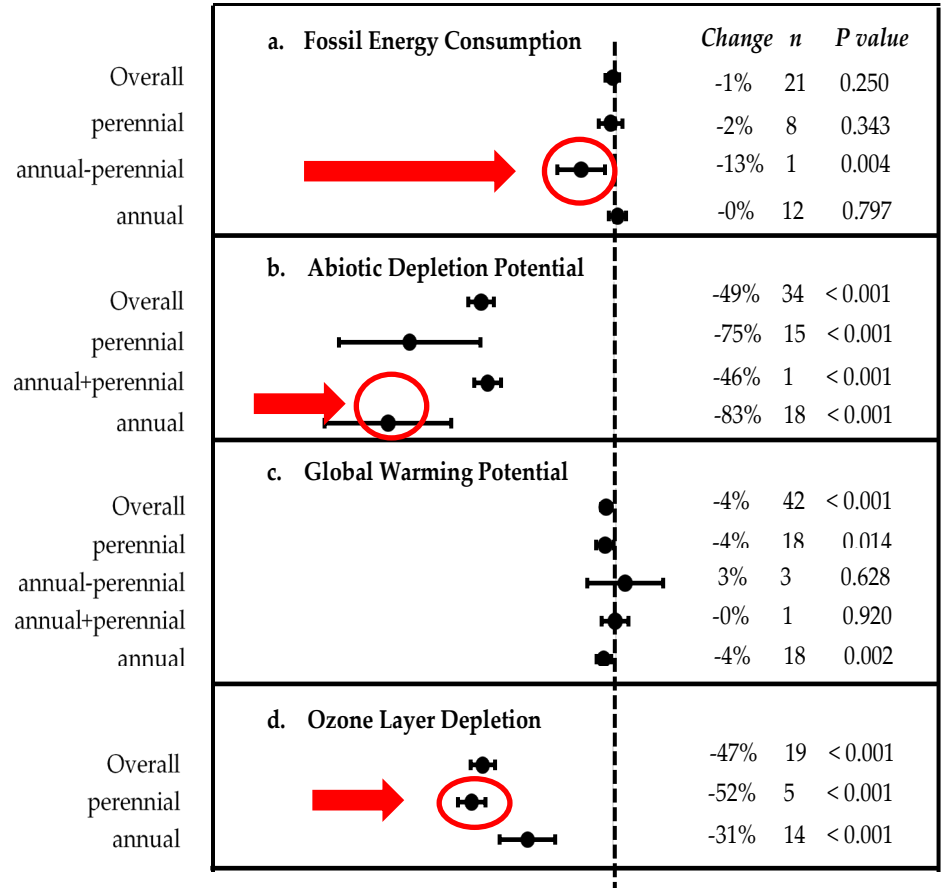


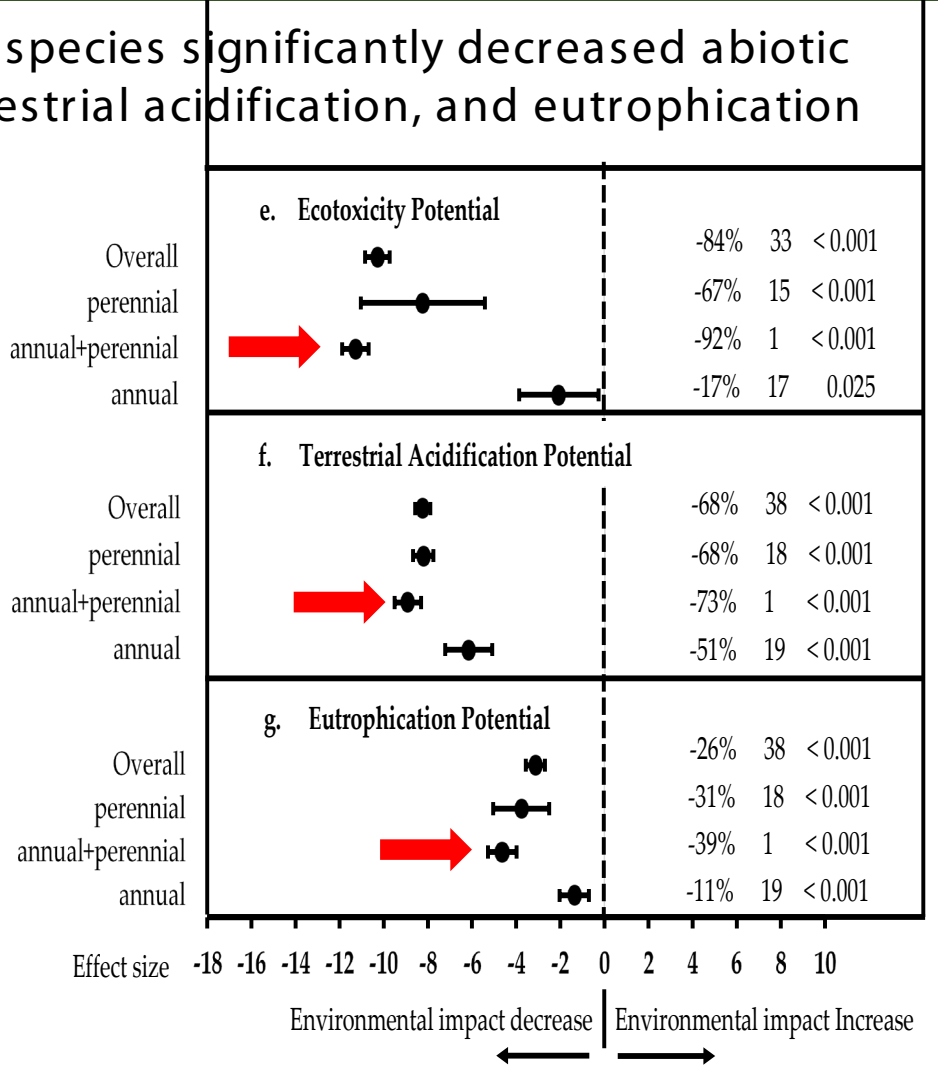



# Due to the lack of heterogeneity, the expected significant environmental benefit of diversified systems over monoculture was not observed.



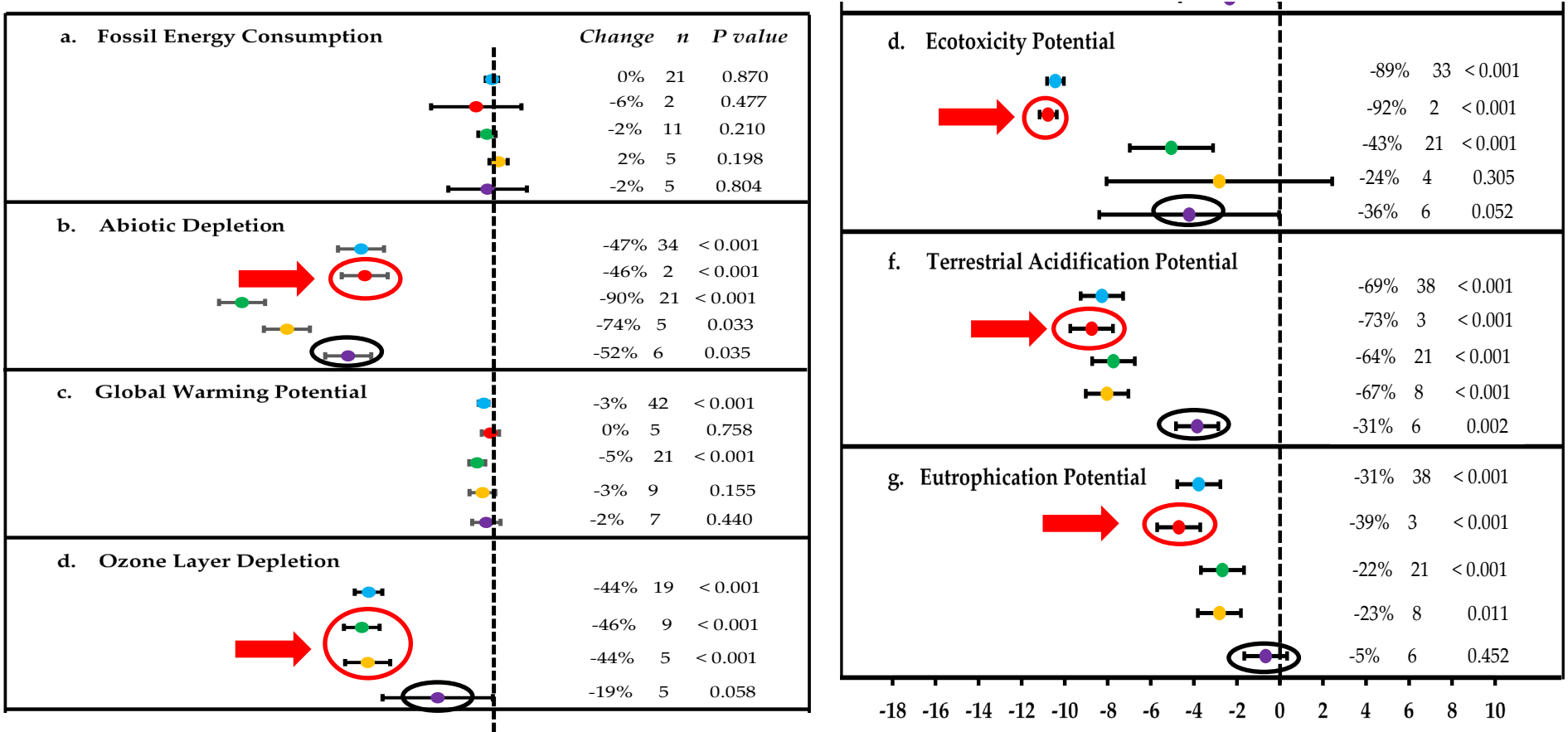
- Intercropping annual and perennial species significantly decreased abiotic depletion potential, ecotoxicity, terrestrial acidification, and eutrophication potential.



- Overall
- DPCS
- AS
- BUA – improved
- BUA - control

- DPCS recorded a 56%, 42%, and 34% more decrease in ecotoxicity, Terrestrial acidification and eutrophication potential, respectively, compared to BAU.



# Conclusions

- Perennial forages significantly reduce terrestrial acidification, ecotoxicity, and eutrophication compared with annual monocultures.
- Diverse perennial circular cropping systems (DPCS), especially with alfalfa, could improve environmental impact categories and are more sustainable than annual monocultures.
- **Future research:**
- Continue measuring and modelling emissions from cropping systems with increased perenniality and diversity
- Evaluate biodiversity above and below ground

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# Thank you


- Establishing alfalfa in intercropping with sunflower and sorghum to improve alfalfa yield and profitability. Award no. 2022-70005-38225.
- Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems (RESILIENCE CAP). Award no. 2021-68012-35917
- Alfalfa management practices and their effect on arbuscular mycorrhizal fungi (AMF) populations- towards improving health, productivity, and sustainability of alfalfa production. Award no. 2019-70005-30239.
- CropSys-CAP- A novel management approach to increase productivity, resilience, and long-term sustainability of cropping systems in the northern Great Plains Award no. 2016-69004-24784


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USDA NIFA

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# Thank you

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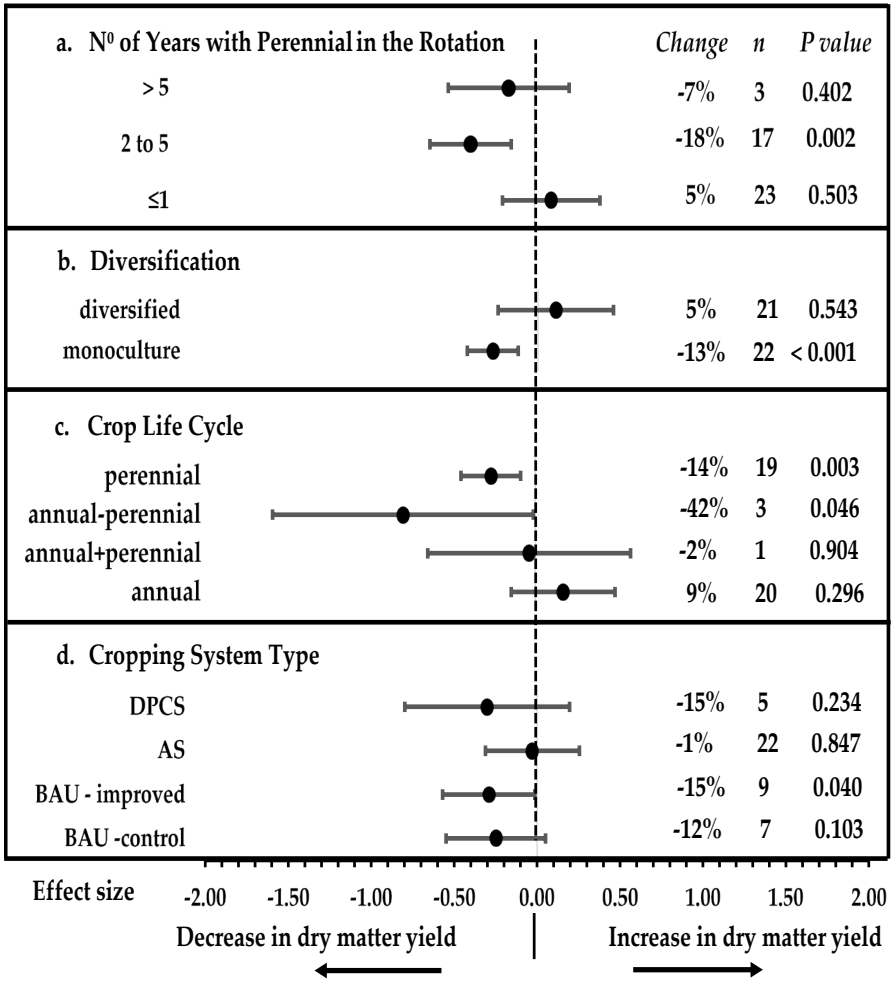
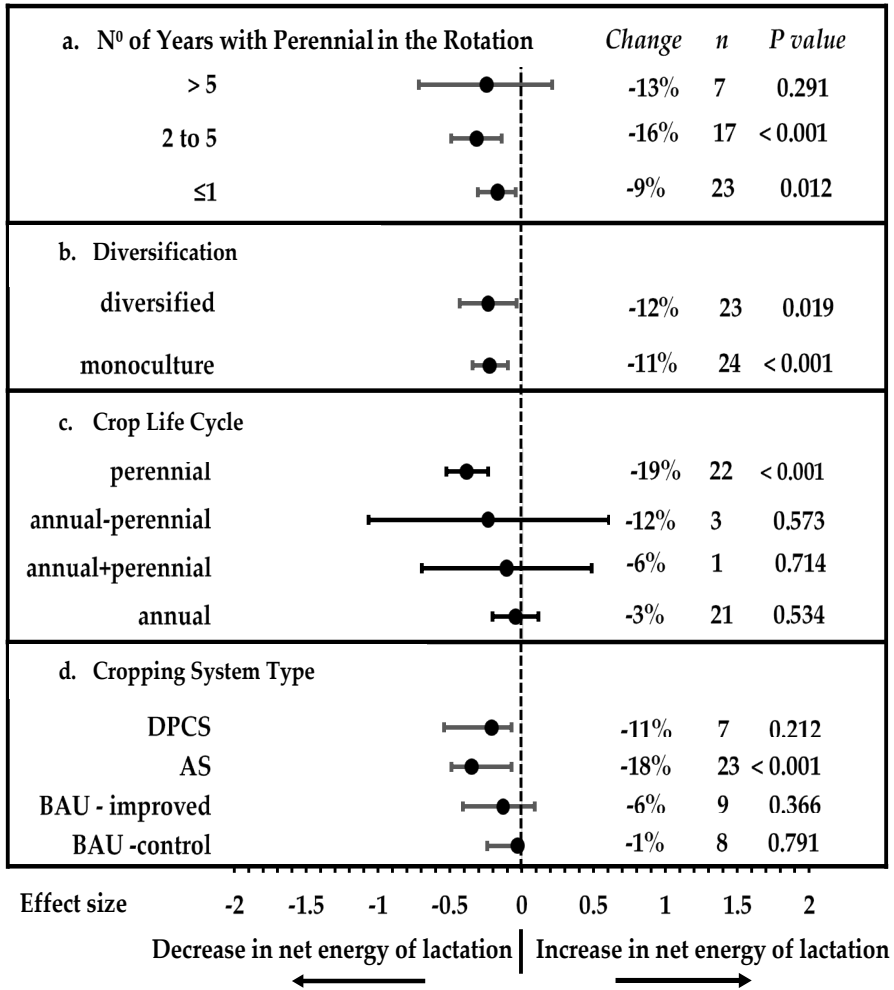

a. Nº of Years with Perennial in the Rotation
Change
n
P value
> 5
-7%
3
0.402
2 to 5
-18%
17
0.002
≤1
5%
23
0.503
b. Diversification
diversified
5%
21
0.543
monoculture
-13%
22
< 0.001
c. Crop Life Cycle
perennial
-14%
19
0.003
annual-perennial
-42%
3
0.046
annual+perennial
-2%
1
0.904
annual
9%
20
0.296
d. Cropping System Type
DPCS
-15%
5
0.234
AS
-1%
22
0.847
BAU - improved
-15%
9
0.040
BAU -control
-12%
7
0.103
Effect size
-2.00
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
2.00
Decrease in dry matter yield
Increase in dry matter yield


a. Nº of Years with Perennial in the Rotation
Change
n
P value
> 5
-13%
7
0.291
2 to 5
-16%
17
< 0.001
≤1
-9%
23
0.012
b. Diversification
diversified
-12%
23
0.019
monoculture
-11%
24
< 0.001
c. Crop Life Cycle
perennial
-19%
22
< 0.001
annual-perennial
-12%
3
0.573
annual+perennial
-6%
1
0.714
annual
-3%
21
0.534
d. Cropping System Type
DPCS
-11%
7
0.212
AS
-18%
23
< 0.001
BAU - improved
-6%
9
0.366
BAU -control
-1%
8
0.791
Effect size
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Decrease in net energy of lactation
Increase in net energy of lactation