Species Mixtures May Enhance Disease and Water Use Benefits Under Climate Change

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Introduction

Throughout agricultural history, intercropping, the simultaneous cultivation of more than one species in close proximity, has been the dominant system of farming. Although industrialization has emphasized monoculture, there is strong evidence that species mixtures often provide greater productivity and resilience, representing both mitigation and adaptation to climate change. Indeed, Project Drawdown includes related forms of agricultural diversification in its carbon-reduction ranking, including agroforestry, tree intercropping, and silvopastoralism.

Here we present empirical evidence that two forms of resilience provided by intercropping may be particularly relevant in a changing climate.

- **Plant Disease.** The range of many diseases is expected to expand as climate warms. Therefore areas which have not historically experienced particular diseases may begin to confront them, likely near the margins of their current range initially.
- **Moisture Stress.** Changes in precipitation and evaporation, and more frequent droughts and flooding, mandate a farming strategy that responds well to unpredictable, often opposite extremes. There is anecdotal evidence that intercropping advantages may be most apparent in such stressful conditions.

Intercropping and Disease

Crop diseases are frequently reduced by species mixtures . . .

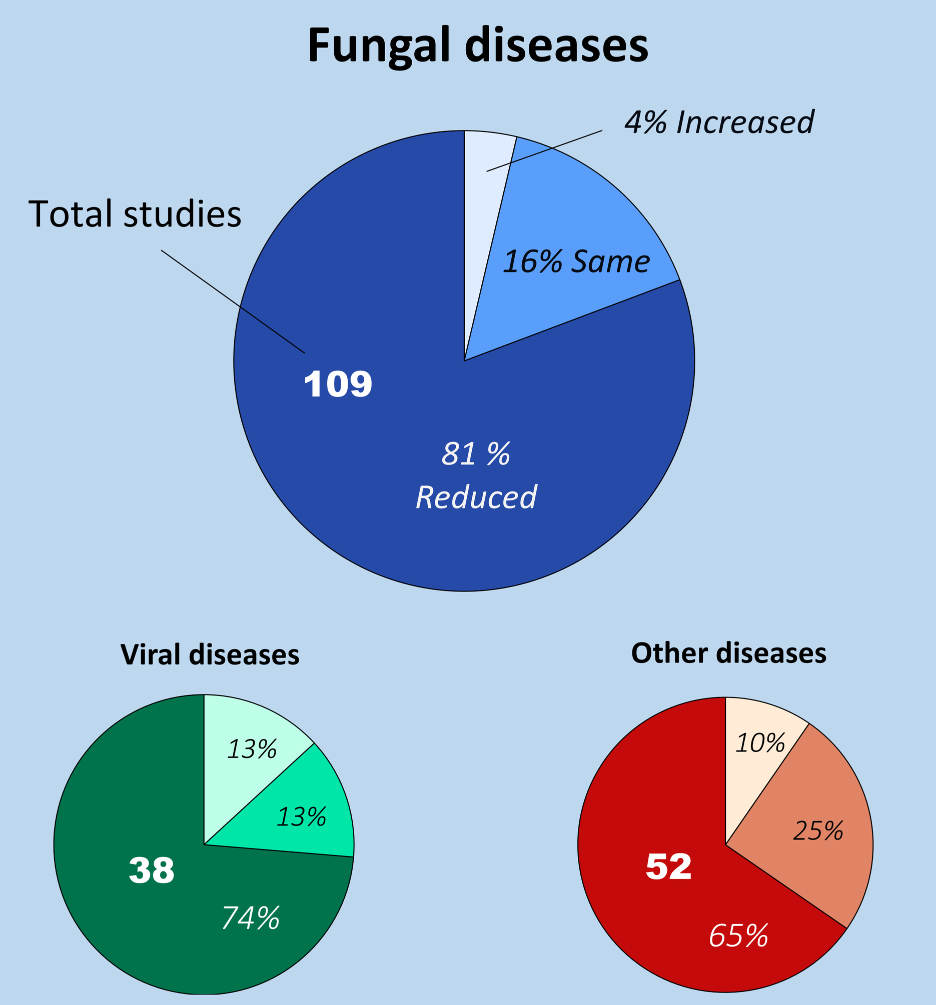


Fig. 1. Effect of intercropping on types of plant disease. Charts derived from previously-published review.[1]

Fig. 2. (right) Disease progress curves for leaf spot of peanut intercropped with corn in a long-term study.[2] Intercropping reduced Area Under the Disease Progress Curve (AUDPC) (p<.05) in locations with historically low peanut production and disease levels (upper graph), but not at the Peanut Belt Research Station (lower graph), a heavy production/disease area.

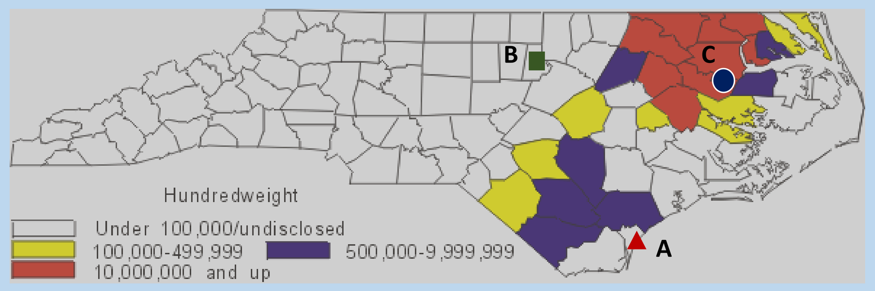
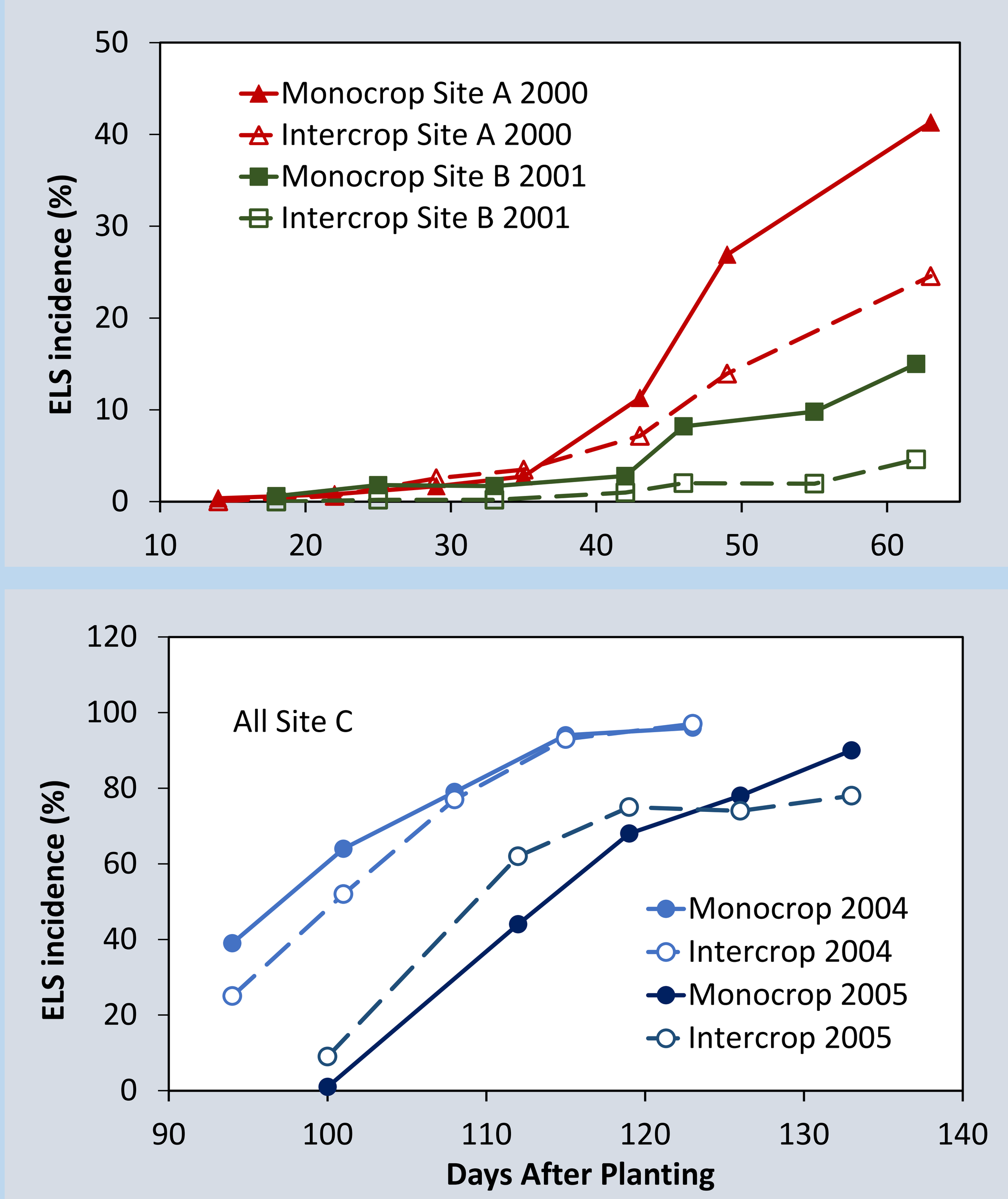


Fig. 3. Peanut production areas in North Carolina at time of study. Experimental site locations are indicated by corresponding symbols in Fig. 2.

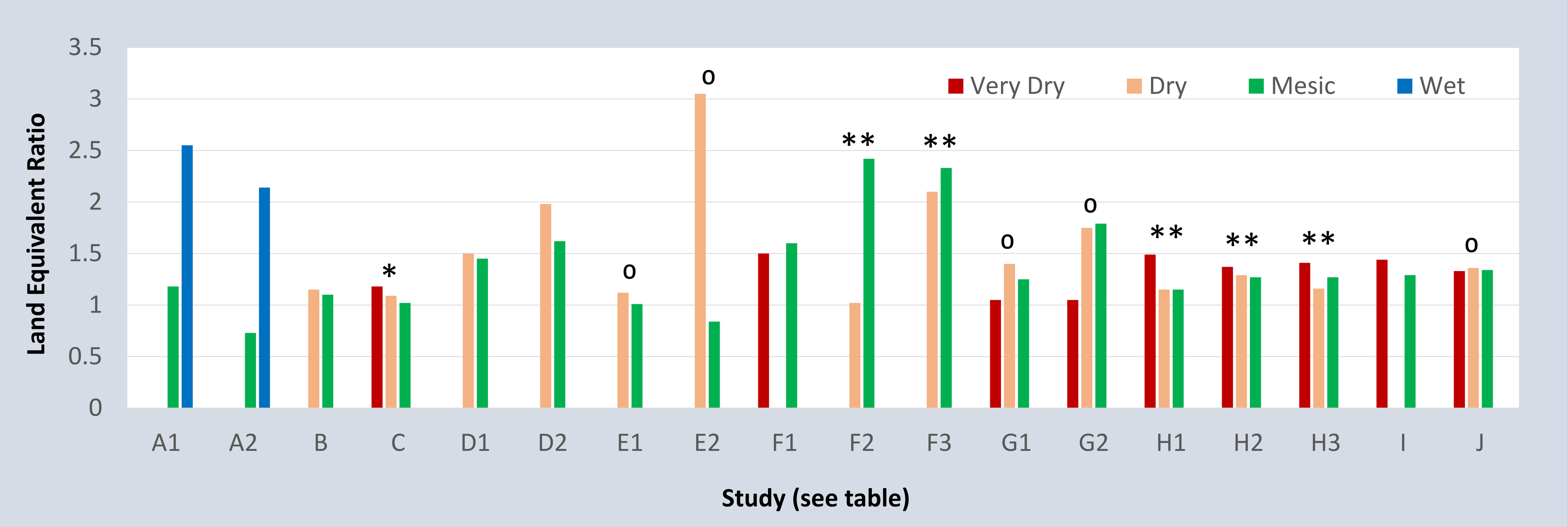
. . . and for peanut leaf spot, this is most effective where historic disease levels are low (upper graph).



Intercropping and Moisture Stress.

Yield is generally increased by intercropping, and this effect may be heightened under extreme moisture conditions.

Fig. 4. Land Equivalent Ratio (LER)† for multiple studies in which moisture stress was present. LER is a unitless ratio expressing productivity of intercrops relative to monocrops; values >1 indicate greater overall yield of intercrop than monocrop. Excess moisture occurs in A alone; inadequate moisture occurred in all other studies. Details given in Table 1. *, ** indicate LER significantly different at p<.05 or p<.01, respectively. ⁰ indicates LER difference statistics were not reported.



Study	Crops	Source of Variation	Location	Reference
A1	Rice + Millet	Irrigation with simulated flooding	Namibia	Awala et al. (2016) *Eur. J. Agron.* 80:105-112.
A2	Rice + Sorghum			
B	Chickpea + Mustard	Irrigation v. rainfed	India	Abraham et al. (2010) *Legume Res.* 33:10-16.
C	Lentil + Isabgol (*Psyllium*)	Three irrigation intervals	Iran	Asgharipour & Rafie (2010) *American-Eurasian J. Sus. Agric.* 4:341-348.
D1	Sorghum + Bottle gourd	Irrigation v. rainfed	South Africa	Chimonyo et al. (2016) *Agric. Water Manag.* 165:82-96.
D2	Sorghum + Cowpea			
E1	Pearl millet + Rice, Upper slope	Rain shelter with or without irrigation	Japan	Izumi et al. (2018) *Plant Produc. Sci.* 21:8-15.
E2	Pearl millet + Rice, Mid-slope			
F1	Corn + Cowpea, on-farm trial	Rainfall, two years, one normal and one 68% < average	Zimbabwe	Masvaya et al (2017) *Field Crops Res.* 209:73-87.
F2	Corn + Cowpea, research station, simultaneous planting	Rainfall, two years, one normal and one 44% < average		
F3	Corn + Cowpea, research station, delayed cowpea planting			
G1	Pearl millet + cowpea, Low density	Three irrigation levels	India	Nelson et al. (2018) *Field Crops Res.* 217:150-166.
G2	Pearl millet + cowpea, High density			
H1	Corn + Soybean, Low nitrogen	Rainfall, three sites on continuum from arid/sandy→moist/clay	Mozambique	Tsujimoto et al. (2015) *Plant Prod. Sci.* 18:365-376.
H2	Corn + Soybean, Med nitrogen			
H3	Corn + Soybean, High nitrogen			
I	Corn + Common & Mung Bean in sequence	Rainfall, two years, one normal and one drought	Ethiopia	Worku (2014) *Exp. Agric.* 50:90-108.
J	Corn + wheat	Three irrigation levels	China	Yang et al. (2011) Field Crops Res. 124:426-432.

Table 1. Studies resulting from a literature search for papers in which LER was reported and can be associated with normal and extreme moisture levels, either through natural variation or experimental manipulation.

†Land Equivalent Ratio (LER) is calculated as:

$$LER = \frac{Y_{intA}}{Y_{monoA}} + \frac{Y_{intB}}{Y_{monoB}}$$

where Y_{intA} and Y_{intB} are the yields of species A and B when intercropped, and Y_{monoA} and Y_{monoB} are yields of species A and B when monocropped.

Conclusions

- ***Plant Disease.*** Peanut strip intercropped with corn reduced leaf spot disease by up to 73% in a seven-year study, but results varied by site. Notably, the greatest reduction occurred in areas where the disease was not well established, which may have value with the anticipated spread of pathogens and crops into new areas under climate change. Although this represents only one pathosystem, the same pattern may occur for other wind-dispersed fungal foliar pathogens, and warrants further study.
- ***Moisture Stress.*** In several studies for which Land Equivalent Ratio was reported from a range of moisture conditions, 95% had productivity gains from intercropping (LER>1), and 68% of the LER values were greater under extreme moisture levels than unstressed conditions. This initial survey only suggests a pattern. It is being expanded to incorporate more studies which allow a formal meta-analysis.

These examples indicate that some benefits of intercropping, while valuable in ideal conditions, may be even more pronounced with climate change. This adds to the value of this accessible, low-cost, and age-old practice for future agroecosystems.

References and Acknowledgements

[1]Boudreau, M.A. (2013) *Annu. Rev. Phytopathol.* 51:499-519.
[2]Boudreau, M.A., B.B. Shew, and L.E. Duffie Andrako (2016) *Plant Pathol.* 65:601-611.

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