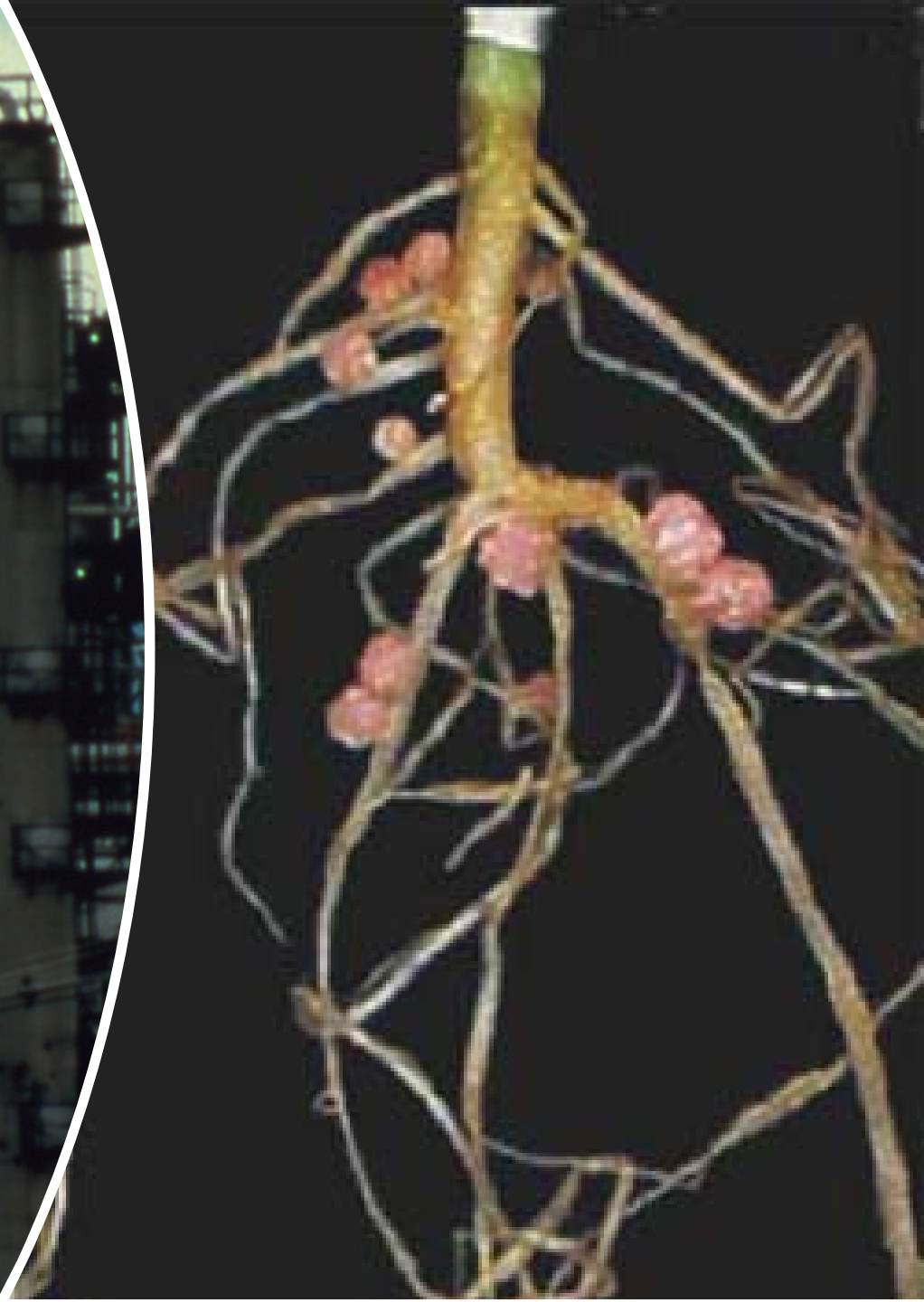
THE
LAND
INSTITUTE

Hugh Warwick

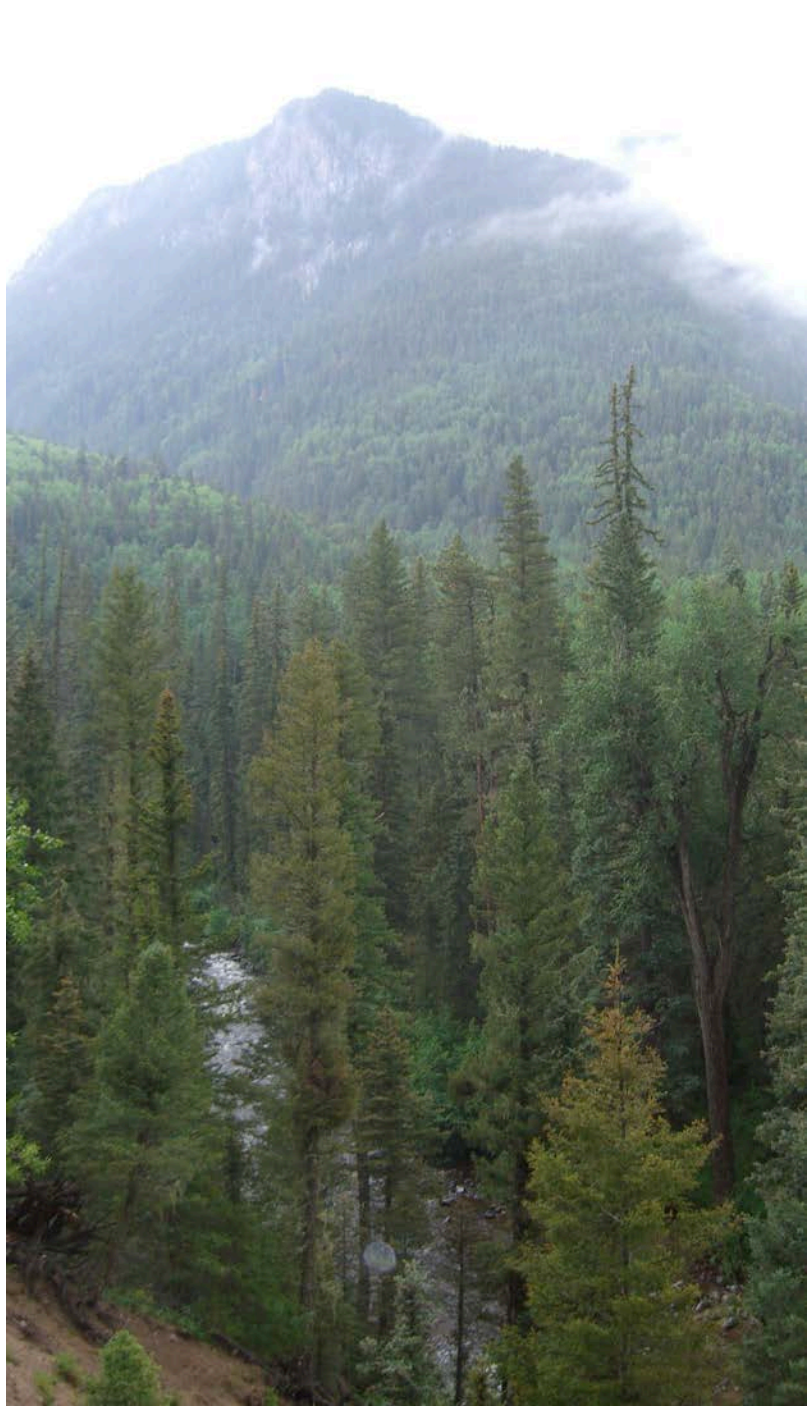
ecological
intensification

nitrogen



The Problem of Agriculture

Photo: Jim Richardson



Natural Ecosystem

Perennial-High Diversity

Ecosystem Services

Soil formation
Maximizes soil organic matter
Resistant to pathogens and insects
Nutrients retained
Weed establishment suppressed
High functioning soil microbiome
High precipitation use efficiency.
No fossil fuel dependence

Agriculture

Annual-Low Diversity

Problems in Agriculture

Soil erosion
Depletes soil organic matter
Vulnerable to pathogens and insects
Unintentional nutrient losses
Weeds establish easily
Low functioning soil microbiome
Low precipitation use efficiency
Heavy fossil fuel dependence

Natural Ecosystem

Agriculture

Perennial-High Diversity

Annual-Low Diversity

Perennial-Moderate Diversity

Ecosystem Services

Soil formation
Maximizes soil organic matter
Resistant to pathogens and insects
Nutrients retained
Weed establishment suppressed
High functioning soil microbiome
High precipitation use efficiency
No fossil fuel dependence

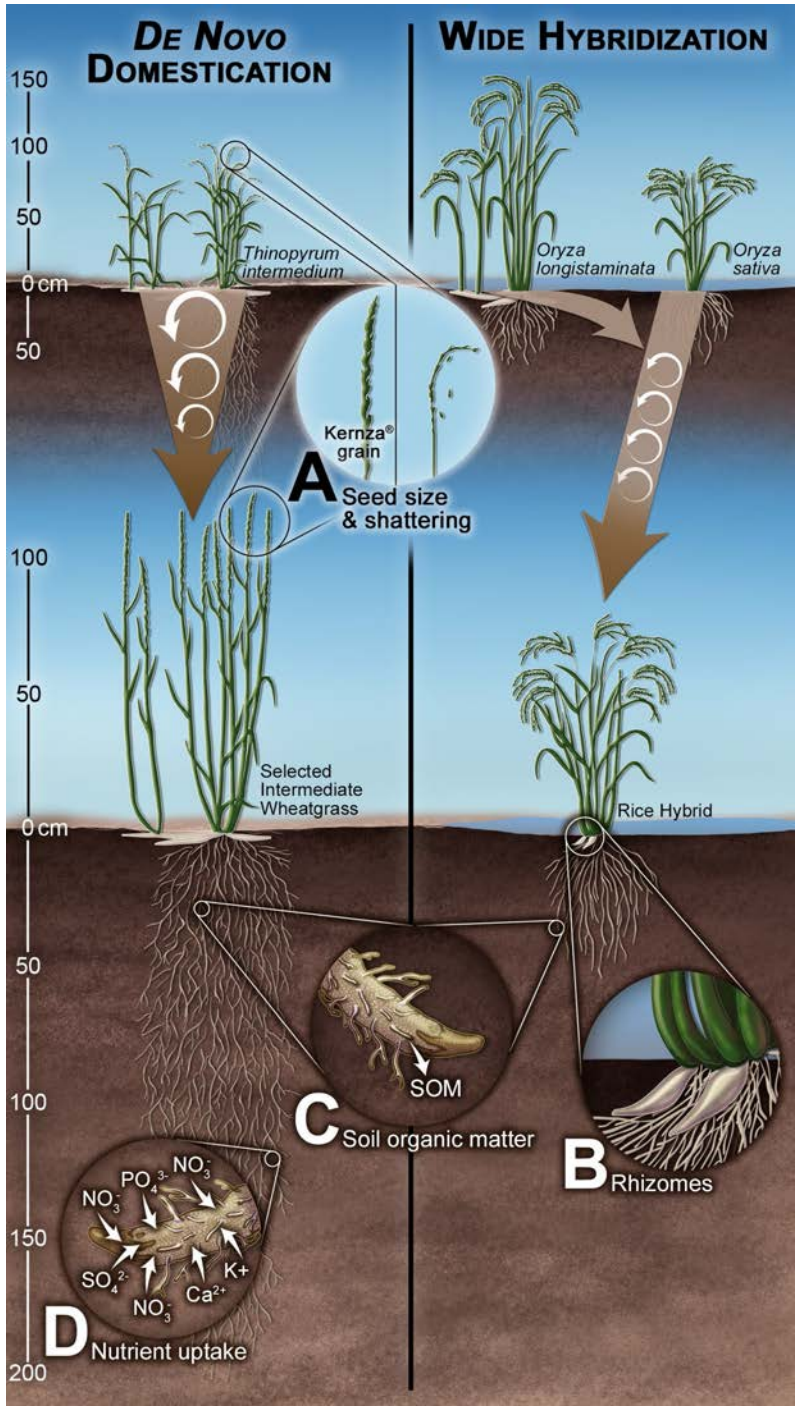
Ecosystem Dis-services

Soil erosion
Reduces soil organic matter
Vulnerable to pathogens and insects
Unintentional nutrient losses
Weeds establish easily
Low functioning soil microbiome
Low precipitation use efficiency
Heavy fossil fuel dependence

Ecosystem Services

Soil formation
Maximizes soil organic matter
Resistant to pathogens and insects
Regulated nutrient losses
Weed establishment suppressed
High functioning soil microbiome
High precipitation use efficiency
Reduced fossil fuel dependence

THE
LAND
INSTITUTE
OFFICE


De Novo Domestication
Wide Hybridization
150
100
50
0 cm
50
100
50
0 cm
50
100
150
200
Thinopyrum intermedium
Oryza longistaminata
Oryza sativa
Kernza® grain
A Seed size & shattering
Selected Intermediate Wheatgrass
Rice Hybrid
SOM
C Soil organic matter
B Rhizomes
NO_3^-
PO_4^{3-}
NO_3^-
NO_3^-
SO_4^{2-}
NO_3^-
Ca^{2+}
$K+$
D Nutrient uptake

de novo Domestication

Oilseeds

Silphium
Silphium integrifolium

Legumes

Sainfoin
Onobrychis vicifolia

Wheatgrass

Kernza®
Thinopyrum intermedium

Perennial wheat

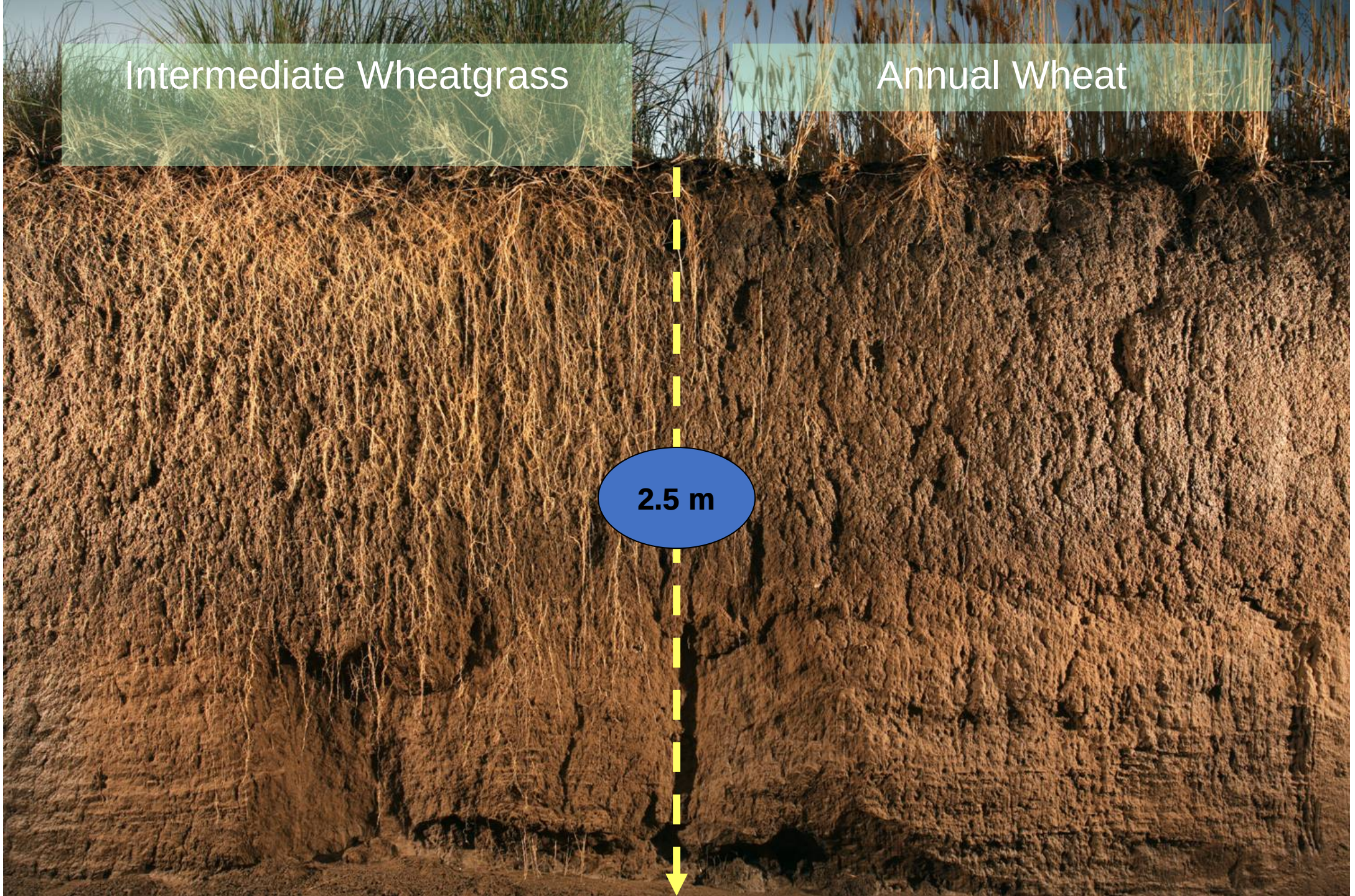
Perennial sorghum

Perennial rice

Wide hybridization

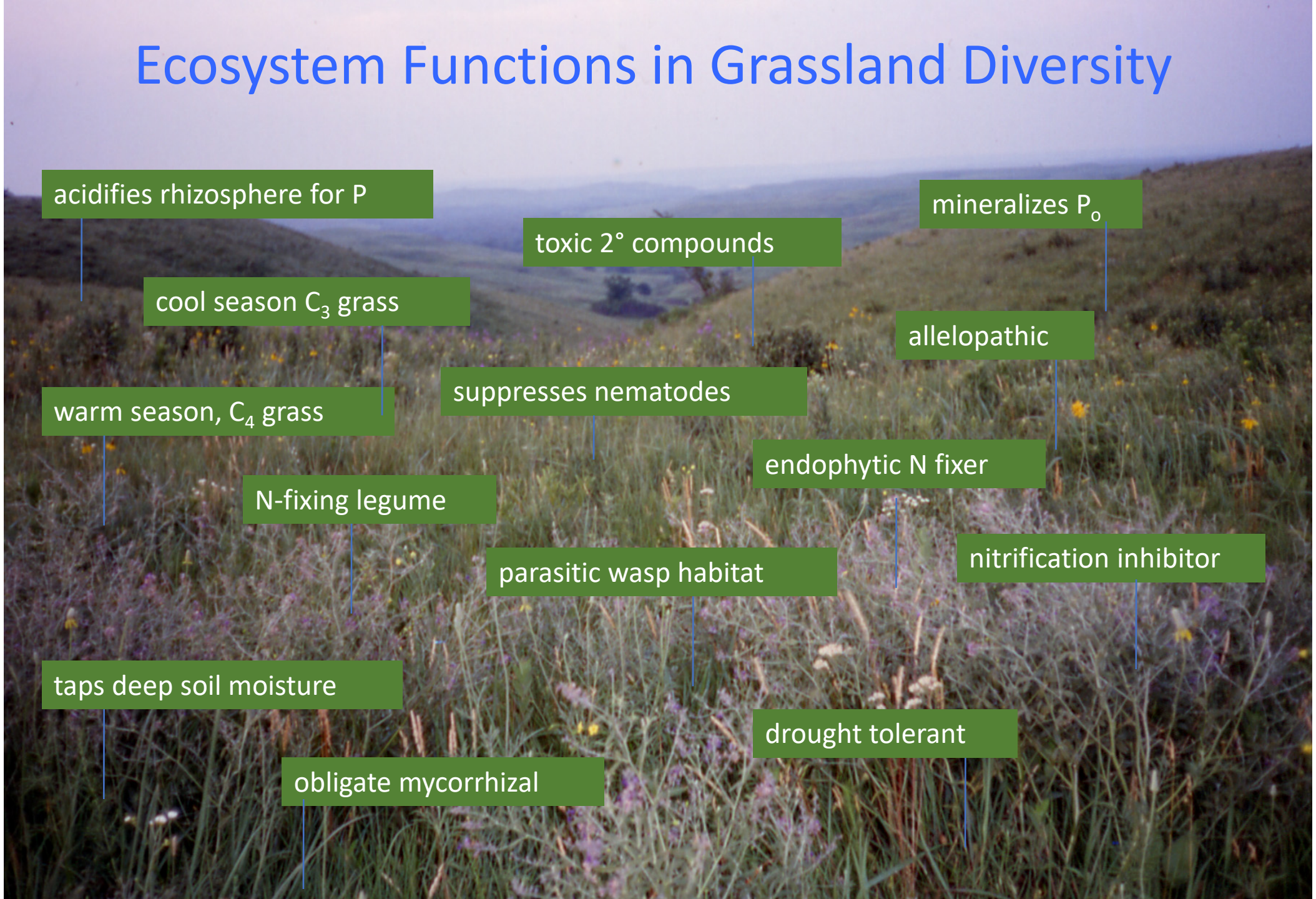
annual **crop** x perennial relative

Silphium oilseed



J. Glover/J. Richardson

Ecosystem Functions in Grassland Diversity



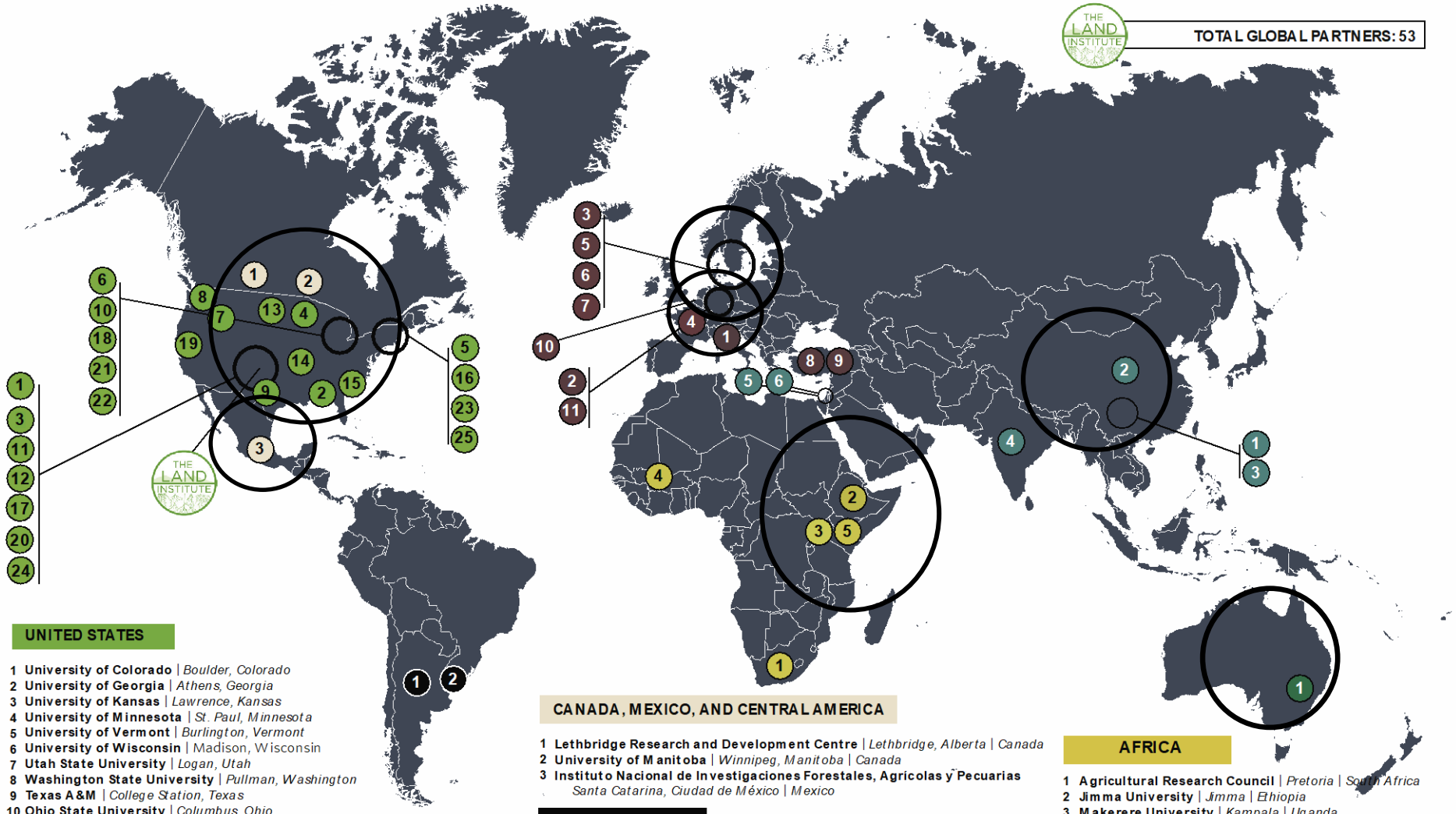
Glover et al. 2010

Intermediate wheatgrass (*Thinopyrum intermedium*) produces Kernza® perennial grain

CASCADIAN FARM
HONEY TOASTED
KERNZA
CEREAL
DEEPLY ROOTED FOR GOOD

BREWED IN PORTLAND, OR
Long Root
WIT
BREWED IN PORTLAND, OR
Long Root
PALE ALE

2019
KERNZA
HARVEST
HONEY-AMBER
LAGER



TOTAL GLOBAL PARTNERS: 53

UNITED STATES

1 **University of Colorado** | *Boulder, Colorado*
2 **University of Georgia** | *Athens, Georgia*
3 **University of Kansas** | *Lawrence, Kansas*
4 **University of Minnesota** | *St. Paul, Minnesota*
5 **University of Vermont** | *Burlington, Vermont*
6 **University of Wisconsin** | Madison, Wisconsin
7 **Utah State University** | *Logan, Utah*
8 **Washington State University** | *Pullman, Washington*
9 **Texas A&M** | *College Station, Texas*
10 **Ohio State University** | *Columbus, Ohio*
11 **Oklahoma State University** | *Stillwater, Oklahoma*
12 **Perennial Agricultural Project Field Station** | *Lawrence, Kansas*
13 **Red River Valley Center – USDA-ARS** | *Fargo, North Dakota*
14 **St. Louis University and Missouri Bontanical Garden & Danforth Center** *St. Louis, Missouri*
15 **North Carolina State University** | *Kannapolis, North Carolina*
16 **Cornell University** | *Ithaca, New York*
17 **Kansas State University** | *Manhattan, Kansas*
18 **Michigan State University** | *East Lansing, Michigan*
19 **University of California, Davis** | *Davis, California*
20 **Colorado State University** | *Fort Collins, Colorado*
21 **Chicago Botanic Garden, Northwestern & Loyola University** | *Chicago, Illinois*
22 **University of Michigan** | *Ann Arbor, Michigan*
23 **Pennsylvania State University** | *State College, Pennsylvania*
24 **USDA-ARS Stored Product Insect and Engineering Research** *Manhattan, Kansas*
25 **Massachusetts Institute of Technology** | *Cambridge, Massachusetts*

CANADA, MEXICO, AND CENTRAL AMERICA

1 **Lethbridge Research and Development Centre** | *Lethbridge, Alberta* | *Canada*
2 **University of Manitoba** | *Winnipeg, Manitoba* | *Canada*
3 **Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias** *Santa Catarina, Ciudad de México* | *Mexico*

SOUTH AMERICA

1 **Museo Paleontologico Edigio Ferugulio** | *Trelow, Patagonia* | *Argentina*
2 **Universidad de la Republia** | *Montevideo* | *Uruguay*

EUROPE

1 **Council for Research and Experimentation in Agriculture** | *Rome* | *Italy*
2 **Max Planck Institute for Plant Breeding Research** | *Köln* | *Germany*
3 **Lund University** | *Lund* | *Sweden*
4 **Perennial Grains Research Program** | *Lyon* | *France*
5 **Swedish University of Agricultural Science** | *Alnarp* | *Sweden*
6 **Swedish University of Agricultural Science** | *Uppsala* | *Sweden*
7 **University of Copenhagen** | *Copenhagen* | *Denmark*
8 **CIMMYT Turkey Wheat Program** | *Ankara* | *Turkey*
9 **Namik Kemal University** | *Nerjez* | *Turkey*
10 **Liege University, TERRA research and teaching center** | Gembloux | *Belgium*
11 **University of Bonn** | *Bonn* | *Germany*

AFRICA

1 **Agricultural Research Council** | *Pretoria* | *South Africa*
2 **Jimma University** | *Jimma* | *Ethiopia*
3 **Makerere University** | *Kampala* | *Uganda*
4 **ICRISAT** | *Bamako* | *Mali*
5 **ICRISAT** | *Nairobi* | *Kenya*

ASIA

1 **Yunnan University** | *Kumming, Yunnan* | *China*
2 **Northwest A&F University** |*Xianyang, Shaanxi* | *China*
3 **Guizhou Normal University** | *Guiyang, Guizhou* | *China*
4 **ICRISAT** | *New Delhi* | *India*
5 **Makaneyyat Project** | *Ramallah* | *Palestine*
6 **Tel Aviv University** | *Tel Aviv* | *Israel*

AUSTRALIA

1 **New South Wales Department of Primary Industries** *Orange, New South Wales* | *Australia*

THE LAND INSTITUTE