Sustainable Land Management & Organic Amendments for Crop Production & Restoration in drylands

ICARDA's experience

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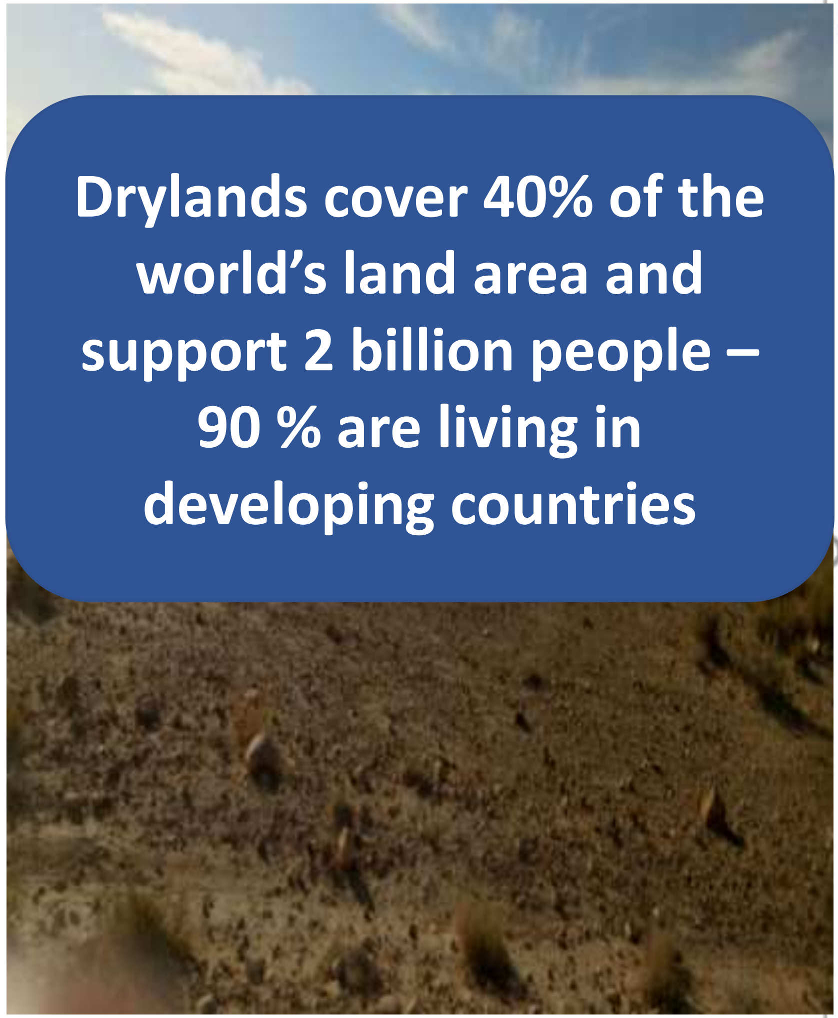
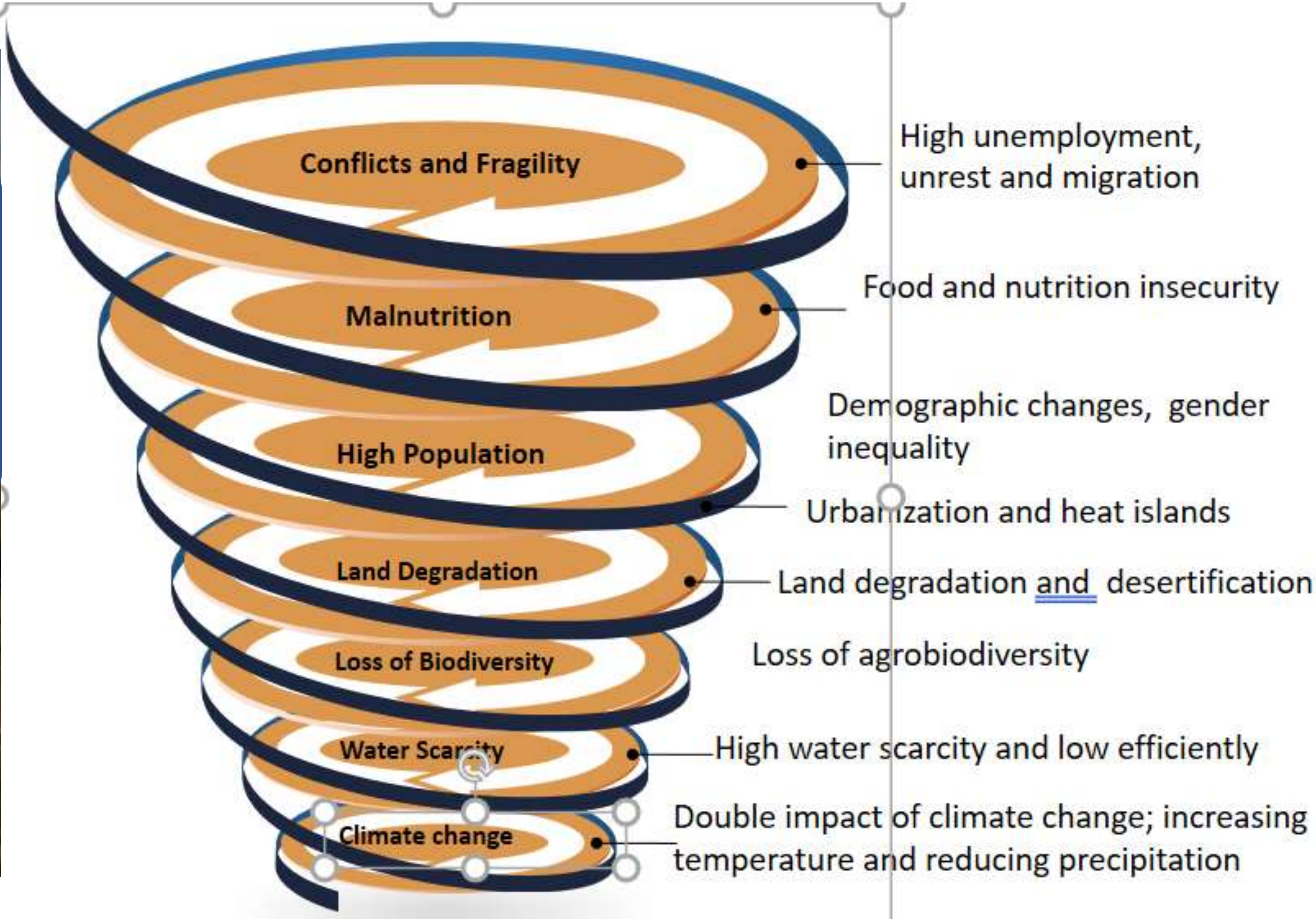
AGRICULTURE IN DRYLANDS IS MORE CHALLENGING



Drylands cover 40% of the world’s land area and support 2 billion people – 90 % are living in developing countries



Conflicts and Fragility

Malnutrition

High Population

Land Degradation

Loss of Biodiversity

Water Scarcity

Climate change

High unemployment, unrest and migration

Food and nutrition insecurity

Demographic changes, gender inequality

Urbanization and heat islands

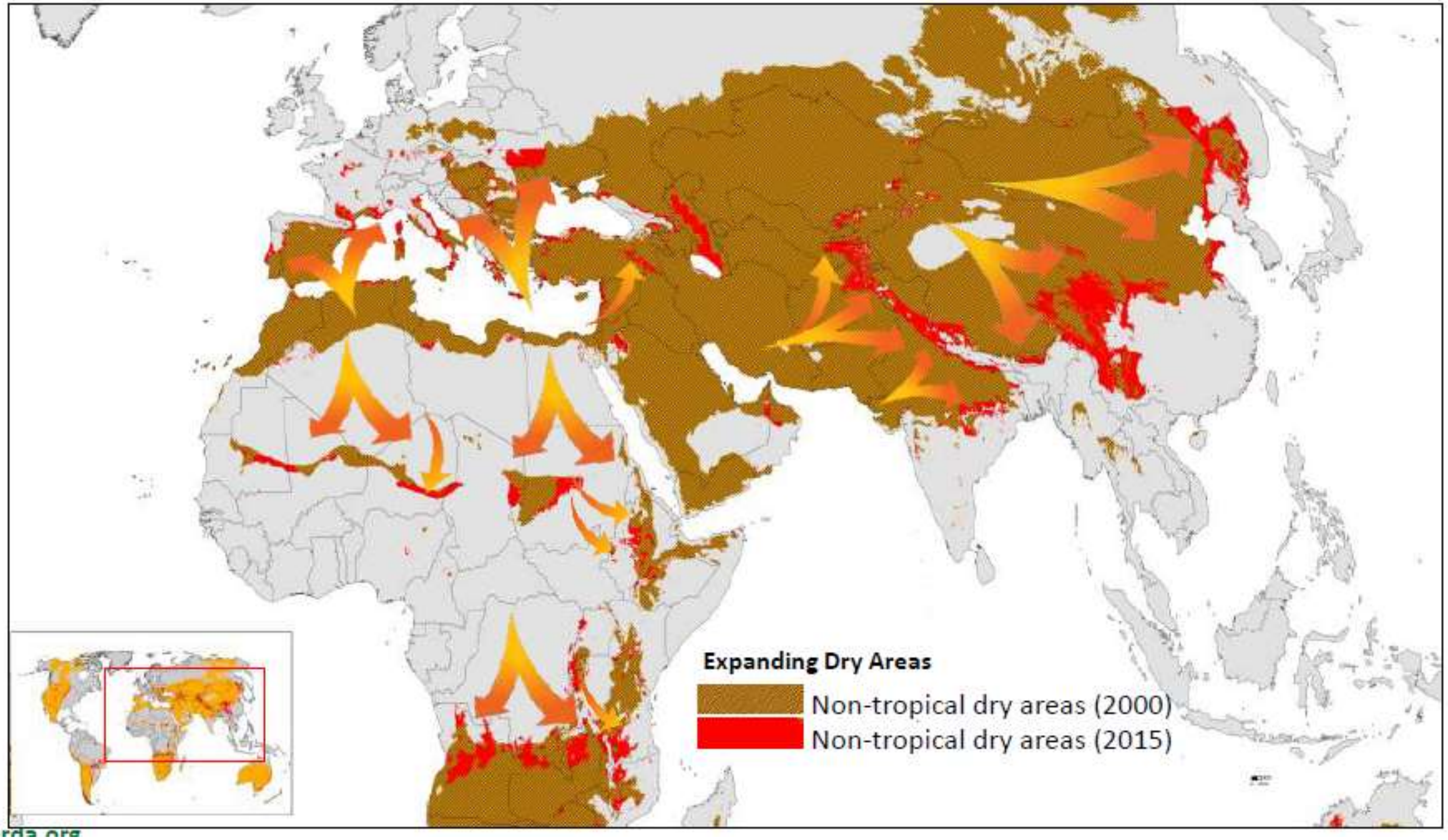
Land degradation and desertification

Loss of agrobiodiversity

High water scarcity and low efficiently

Double impact of climate change; increasing temperature and reducing precipitation

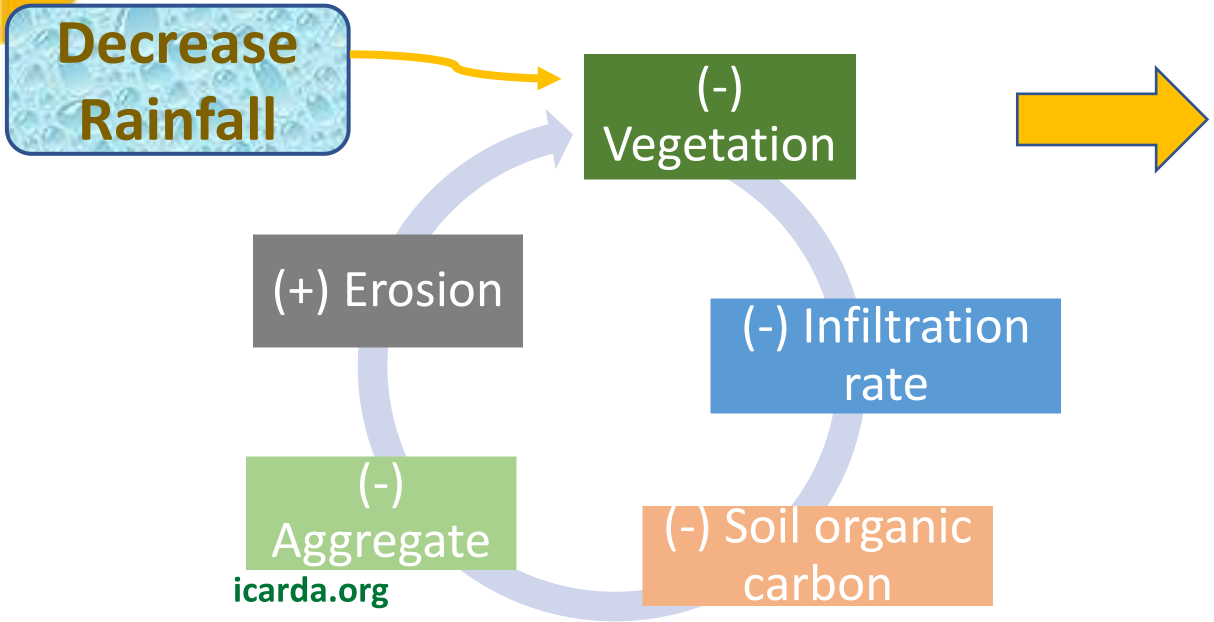
DRYLANDS ARE EXPANDING ACROSS DIFFERENT CONTINENTS



Dry areas can occur in any continent

LAND DEGRADATION IN DEGRADED DRYLAND AREAS

Inter-related problems such as soil degradation, desertification, erosion and climate change impact on sustaining drylands is increasing global level concern.



Decrease Rainfall

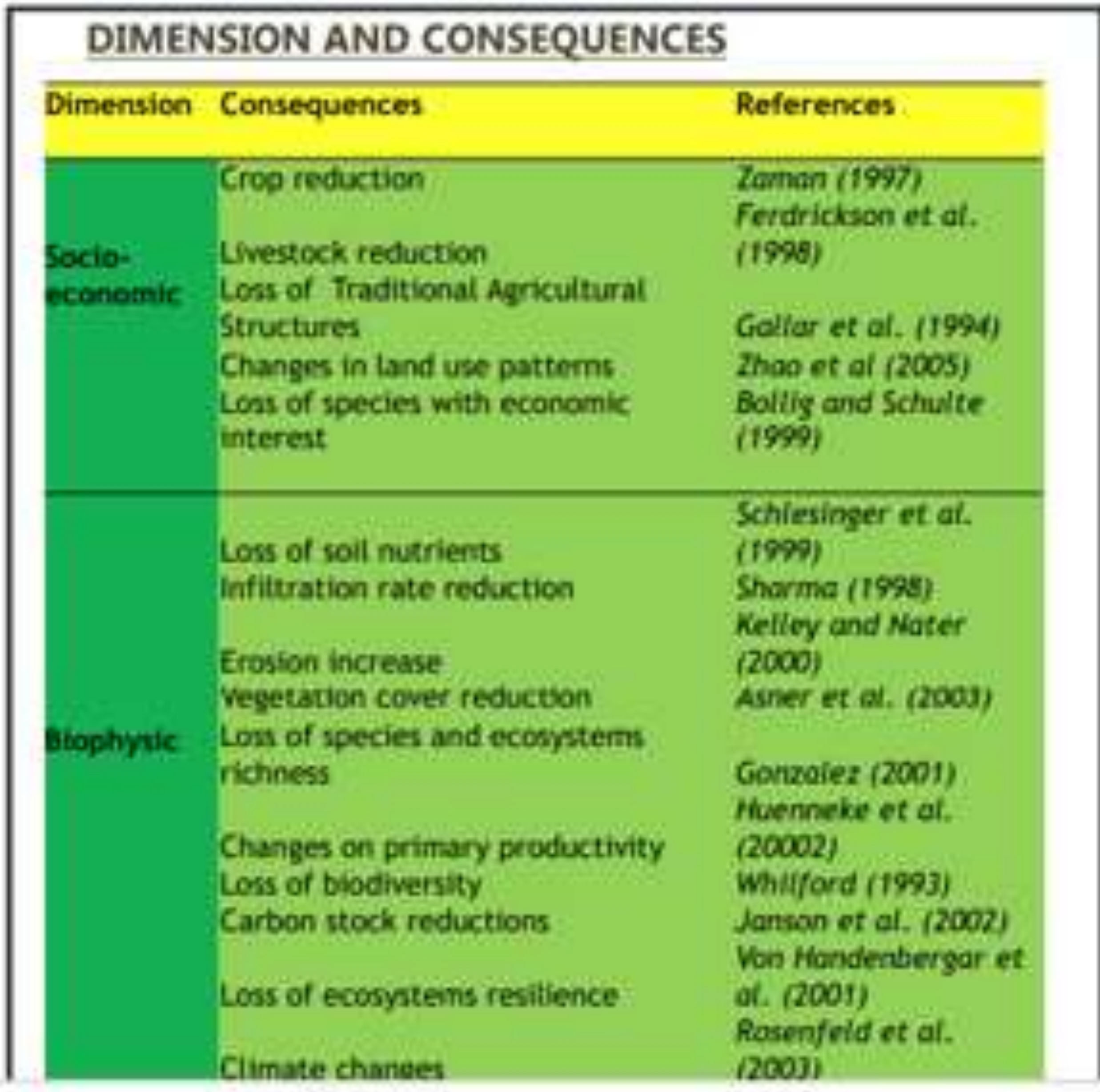
(-) Vegetation

(-) Infiltration rate

(-) Soil organic carbon

(-) Aggregate

(+) Erosion

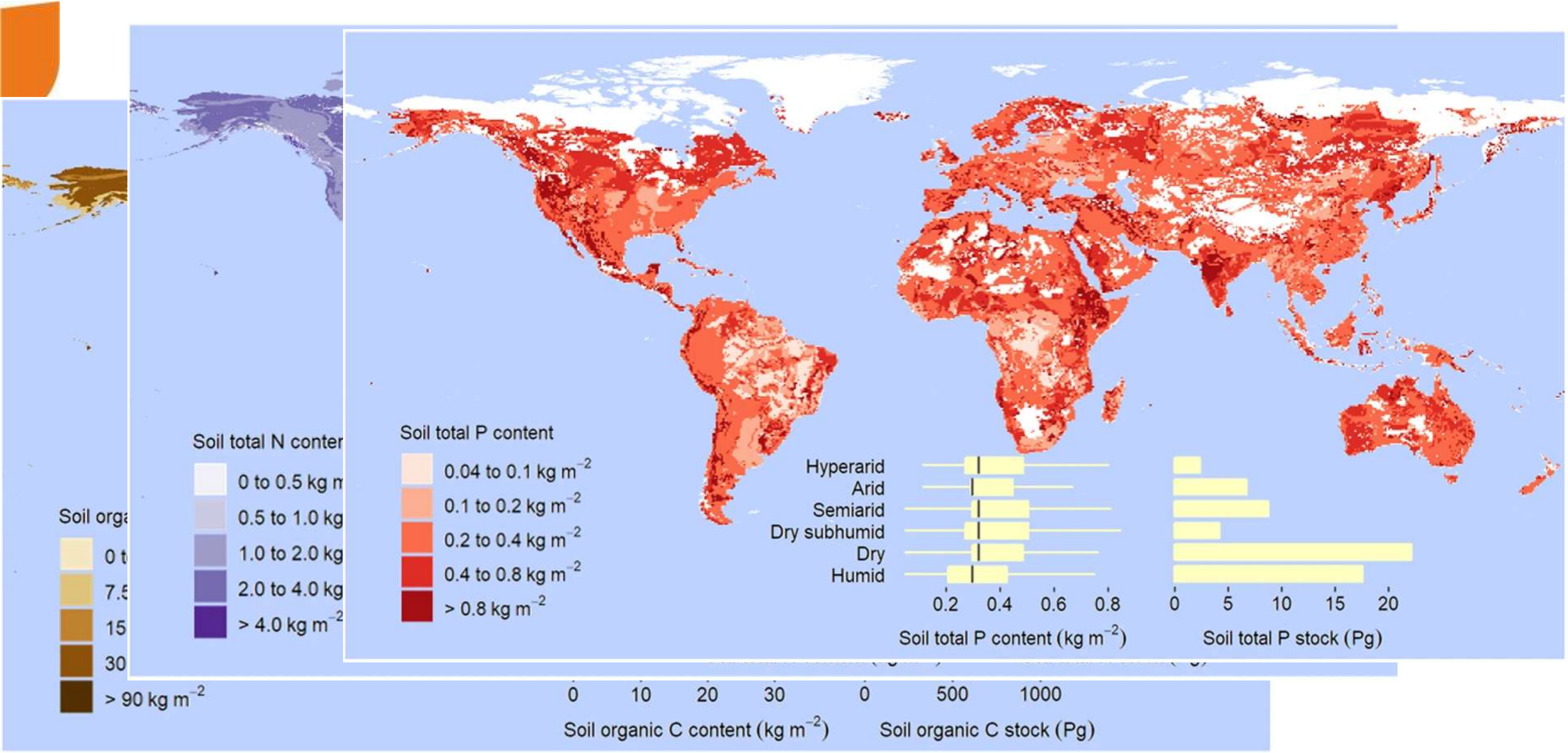


DIMENSION AND CONSEQUENCES

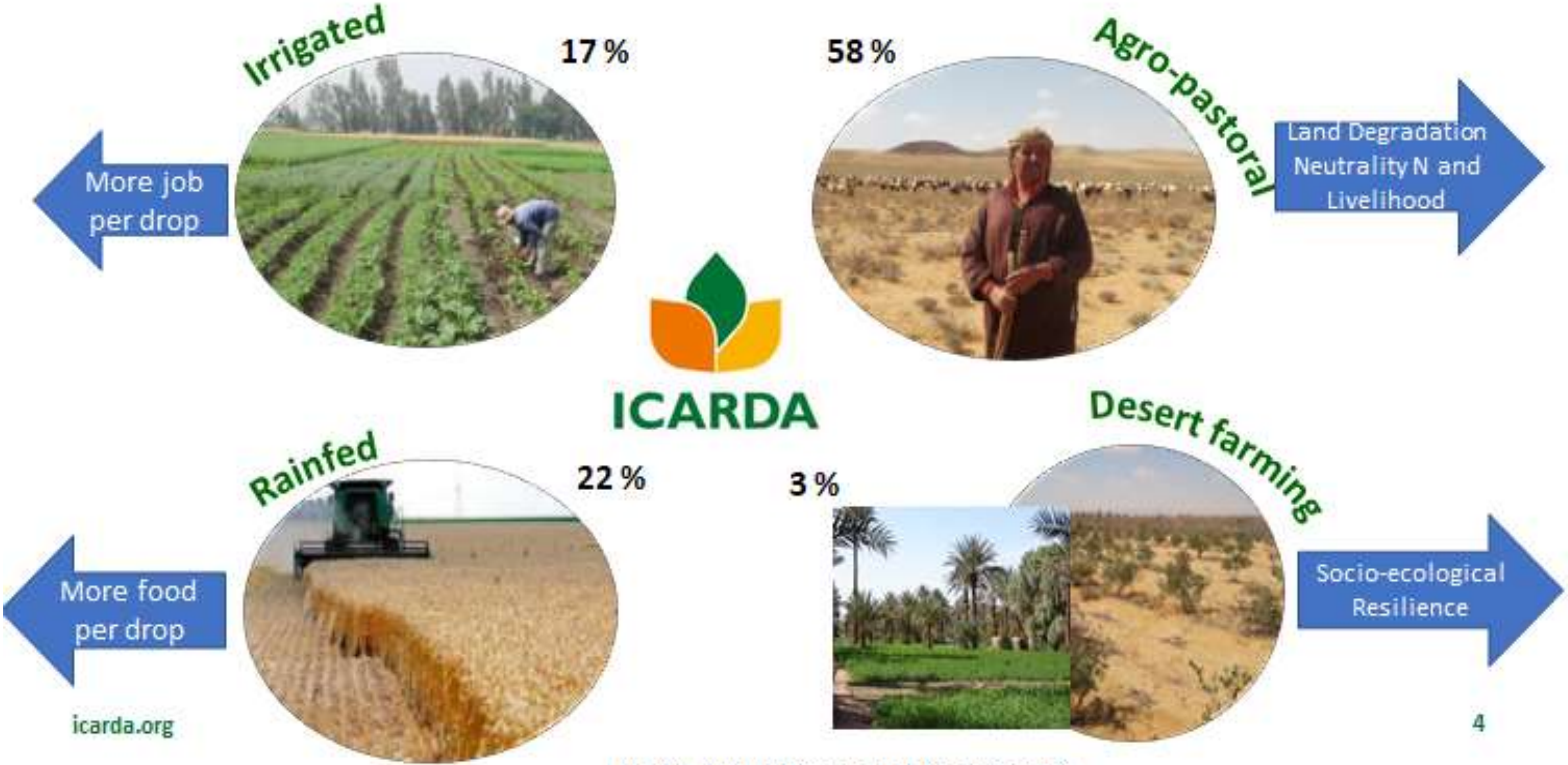
Dimension	Consequences	References
Socio-economic	Crop reduction Livestock reduction Loss of Traditional Agricultural Structures Changes in land use patterns Loss of species with economic interest	*Zaman (1997)* *Ferdrickson et al. (1998)* *Gallar et al. (1994)* *Zhao et al (2005)* *Bollig and Schulte (1999)*
Biophysic	Loss of soil nutrients Infiltration rate reduction Erosion increase Vegetation cover reduction Loss of species and ecosystems richness Changes on primary productivity Loss of biodiversity Carbon stock reductions Loss of ecosystems resilience Climate changes	*Schlesinger et al. (1999)* *Sharma (1998)* *Kelley and Nater (2000)* *Asner et al. (2003)* *Gonzalez (2001)* *Huenneke et al. (20002)* *Whitford (1993)* *Janson et al. (2002)* *Von Handenbergar et al. (2001)* *Rosenfeld et al. (2003)*

DRYLANDS HAS POOR SOIL NUTRIENT CONTENT !

Plaza et al., 2018, Scientific Report. **Soil resources and element stocks in drylands to face global issues**



ICARDA across Africa, Middle East, and Asia



Irrigated

17 %

More job per drop

Agro-pastoral

58 %

Land Degradation Neutrality N and Livelihood

ICARDA

Rainfed

22 %

More food per drop

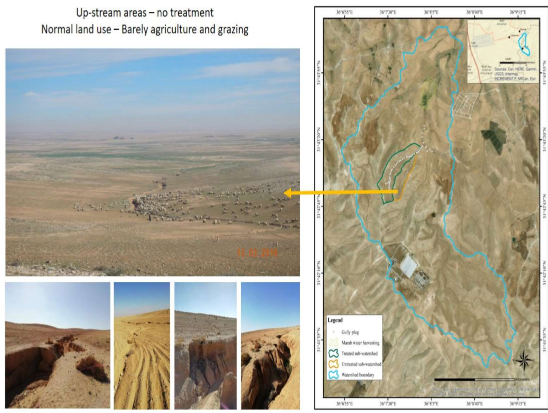
Desert farming

3 %

Socio-ecological Resilience

NENA Agricultural Land (2.5 M km2)

ICARDA'S EFFORT ON SUSTAINABLE LAND AND SOIL MANAGEMENT


Up-stream areas – no treatment
Normal land use – Barely agriculture and grazing

Restoration of degraded land

- Afforestation
- Reduce soil erosion
- Enhancing vegetative cover

Soil organic matter restoration, preservation and enhancement in drylands

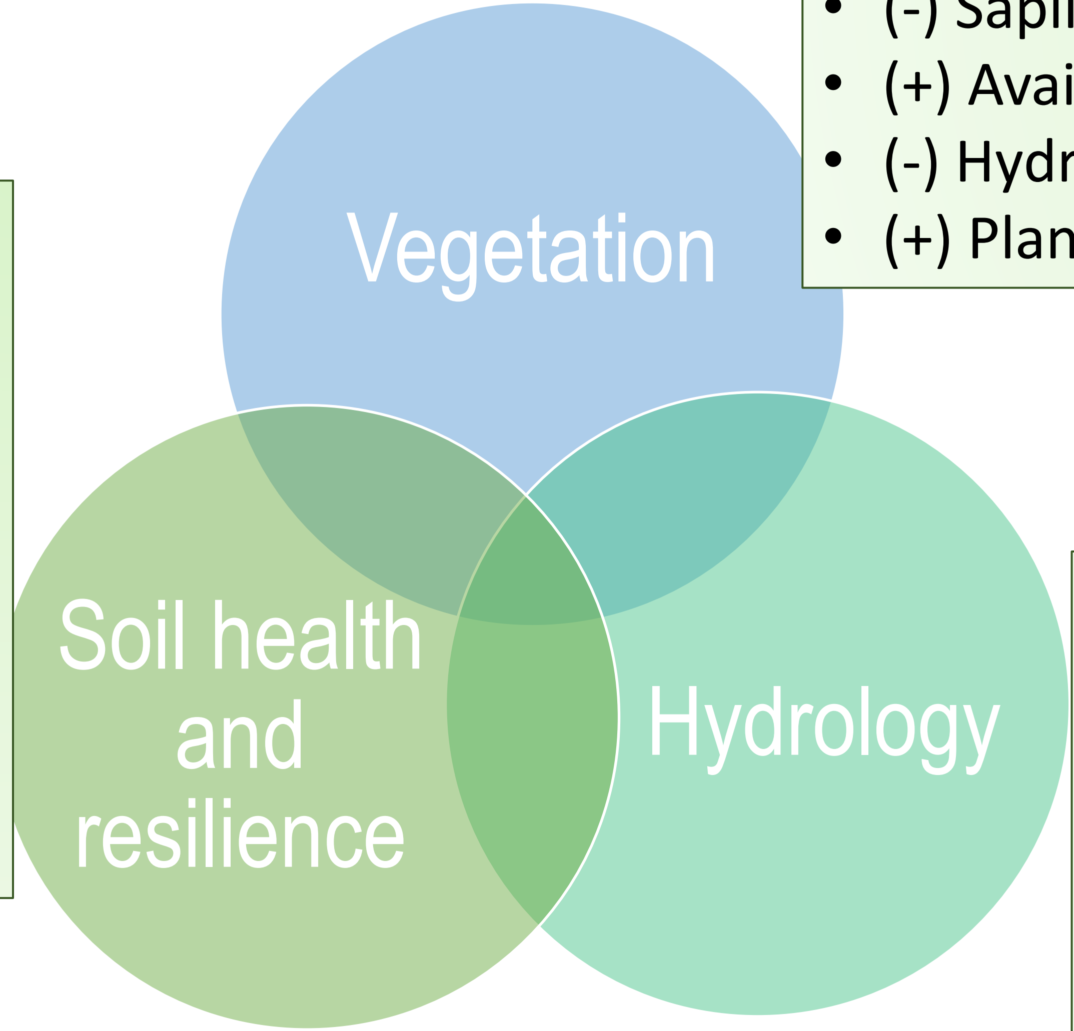
Resilient farming

- Organic amendment
- Mineral fertilization
- Crop rotation/diversification
- Cover crop
- Conservation tillage/agriculture
- Precision water mgt.

Rangeland management

- Reduced grazing intensity
- Regreening
- Good management practice

Three pillars and performance indicators for greening drylands



- (-) Sapling mortality
- (+) Available water for plant
- (-) Hydrological plant stress
- (+) Plant height/canopy/biomass

- (+) Soil organic carbon
- (-) Bulk density
- (+) Soil porosity
- (+) Favors soil aggregation
- (-) Soil & groundwater EC
- (+) Soil nutrient
- (+) Soil microbiota
- (-) Calcium carbonate

- (-) Overland flow
- (-) Erosion decrease
- (+) Soil moisture
- (+) Soil roughness
- (-) Soil sealing and splash

Modified from González et al., 2018

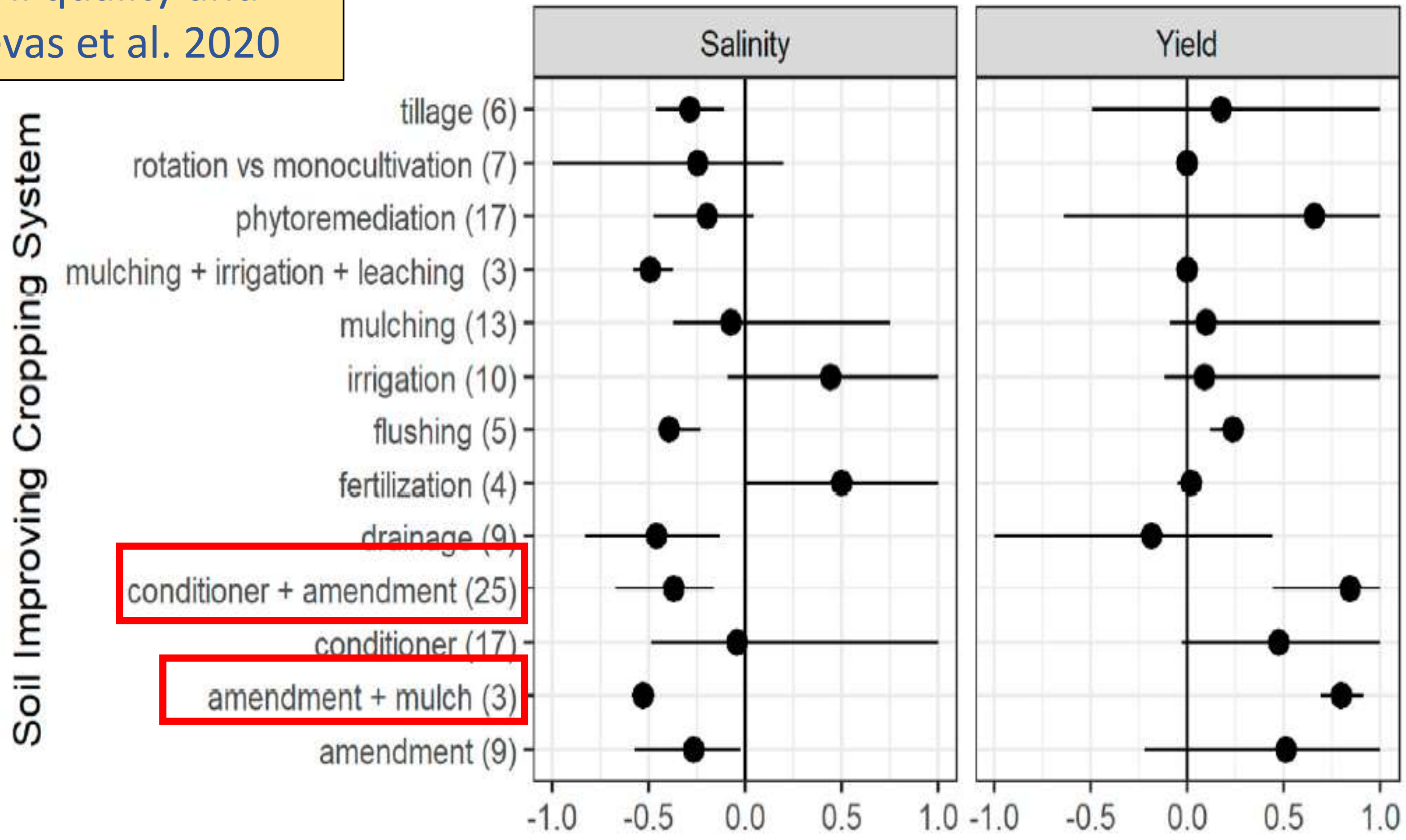
EFFECT OF DIFFERENT SOIL IMPROVEMENT PRACTICES ON SOIL QUALITY AND CROP YIELD

The use of soil amendments in ecosystem restoration can be an effective technique for soil restoration process in degraded drylands and their benefits of improving soil physical, chemical and biological properties

A global meta-analysis of 128 paired soil quality and yield observations from 30 studies Cuevas et al. 2020

Combinations of soil amendments, conditioners, and residue management can contribute to significant reductions of soil salinity with increase crop yields in degrading soil

Source: Cuevas et al., 2020



LAND DEGRADATION & RECYCLING CYCLES CONTROLLED BY SOIL AMENDMENTS !

Types of soil amendments

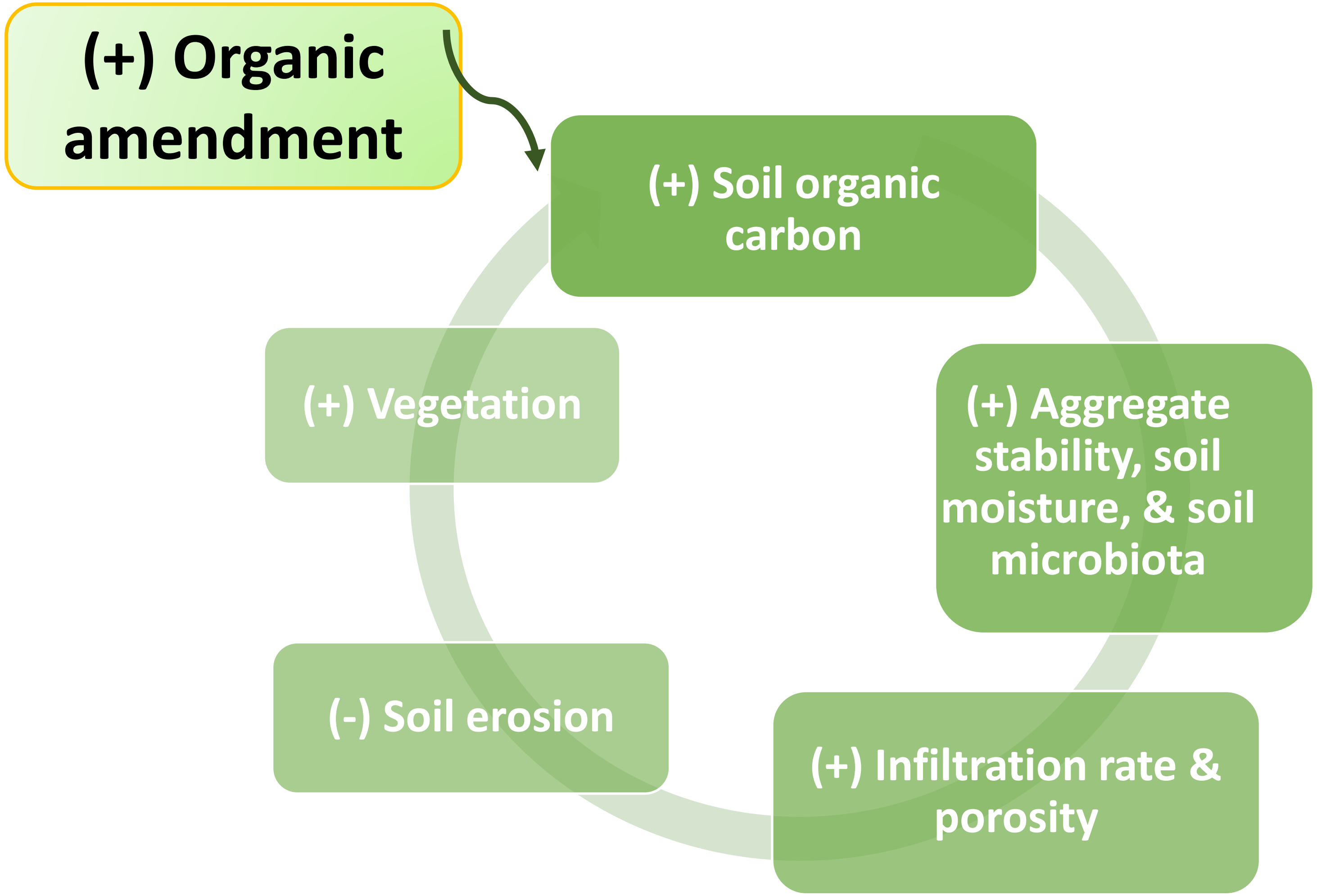
1. Mulch/cover crop
- Organic
- Synthetic

2. BIO-FERTILIZER
- Micro-organism
- Enzymes

3. Sewage sludge

4. Industrial bi-product
- Phosphozypsum
- Bi-products

5. Manures



(+) Organic amendment

(+) Soil organic carbon

(+) Aggregate stability, soil moisture, & soil microbiota

(+) Infiltration rate & porosity

(-) Soil erosion

(+) Vegetation

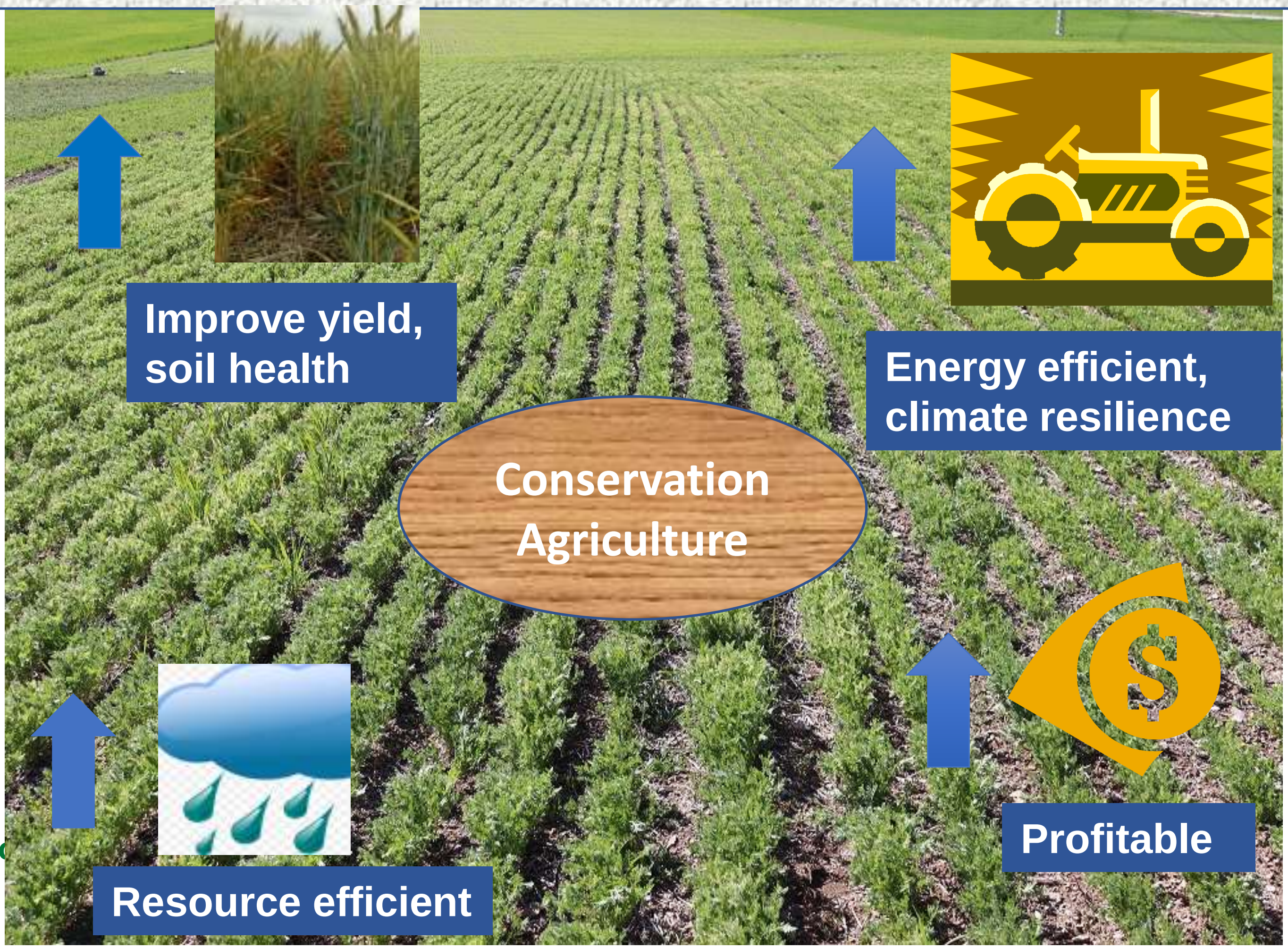
Dryland restoration/productivity enhancement cycle through organic amendments

Modified from González et al., 2018

ICARDA’s research effort on improving degraded drylands

Conservation Agriculture for sustainable intensification of rainfed drylands

Conservation Agriculture: **minimum tillage** + permanent soil cover + **crop rotation** is considered as climate resilience and resource-conserving production practices



Improve yield, soil health

Energy efficient, climate resilience

Conservation Agriculture

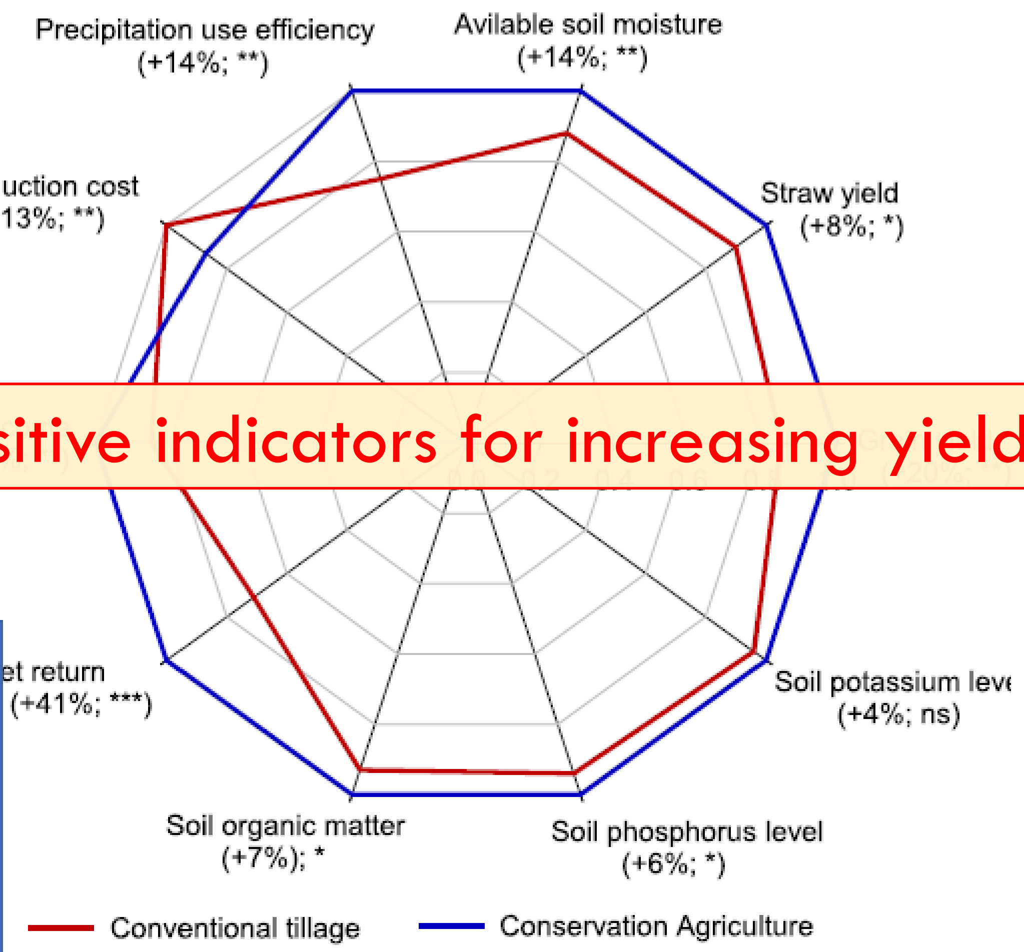
Resource efficient

Profitable

Several science-based evidences verified that adoption of CA can help to improve crop productivity, soil health and resilience

Conservation agriculture :Case study from rainfed drylands of North Africa

Based on the 5 years of field experimentation



CA had higher positive indicators for increasing yield and RUE in drylands than CT

- System productivity: 17.8% ⬆
- Total income: 17.2% ⬆
- Total production cost: reduced by 14.5% ⬇
- Rainfall use efficiency: 30%
- Avilable soil moisture: 14%
- Soil Organic Carbon: 7% ⬆
- Avilable phosphorus: 6%
- Exchangeable potash: 4%

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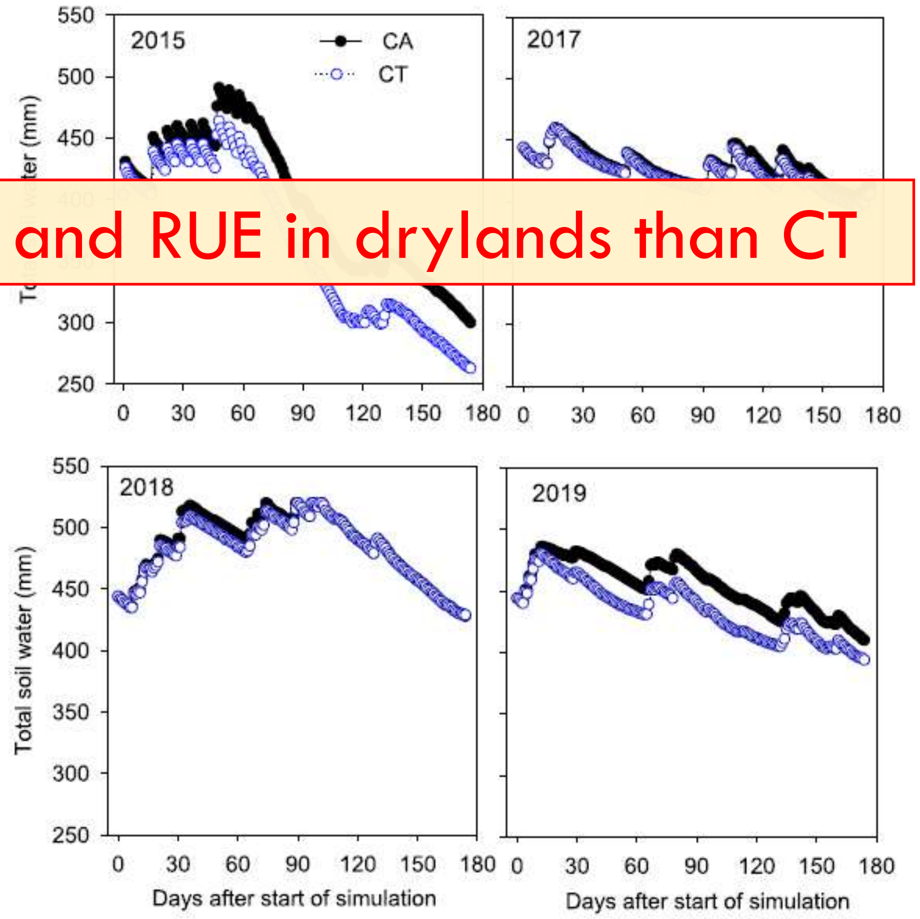
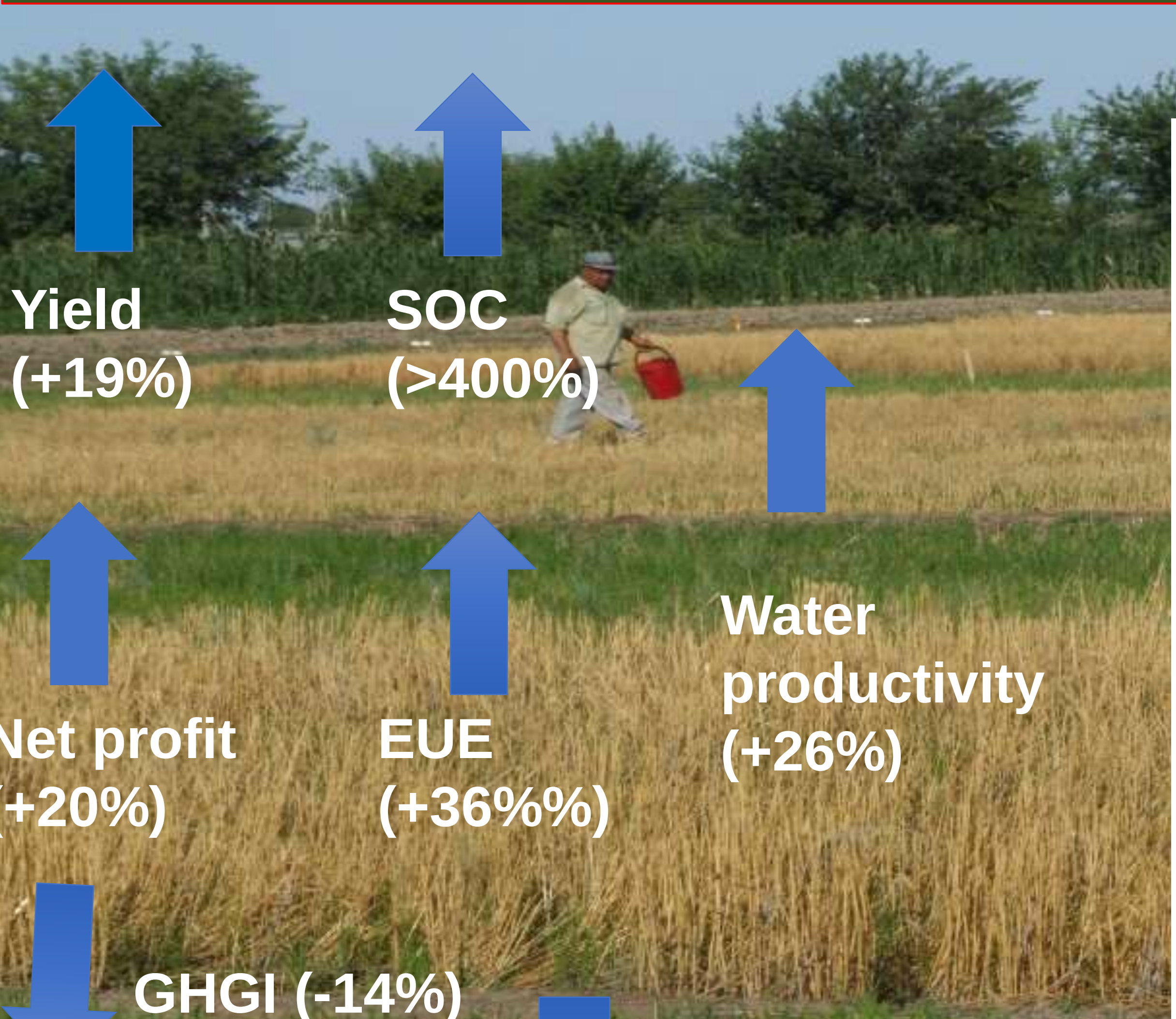
journal homepage: www.elsevier.com/locate/agsy

Conservation agriculture improves agronomic, economic, and soil fertility indicators for a clay soil in a rainfed Mediterranean climate in Morocco

Mina Devkota a,*, Krishna Prasad Devkota b, Shiv Kumar a



Conservation agriculture: Case study in Uzbekistan-Irrigated drylands



Yield (+19%)

SOC (>400%)

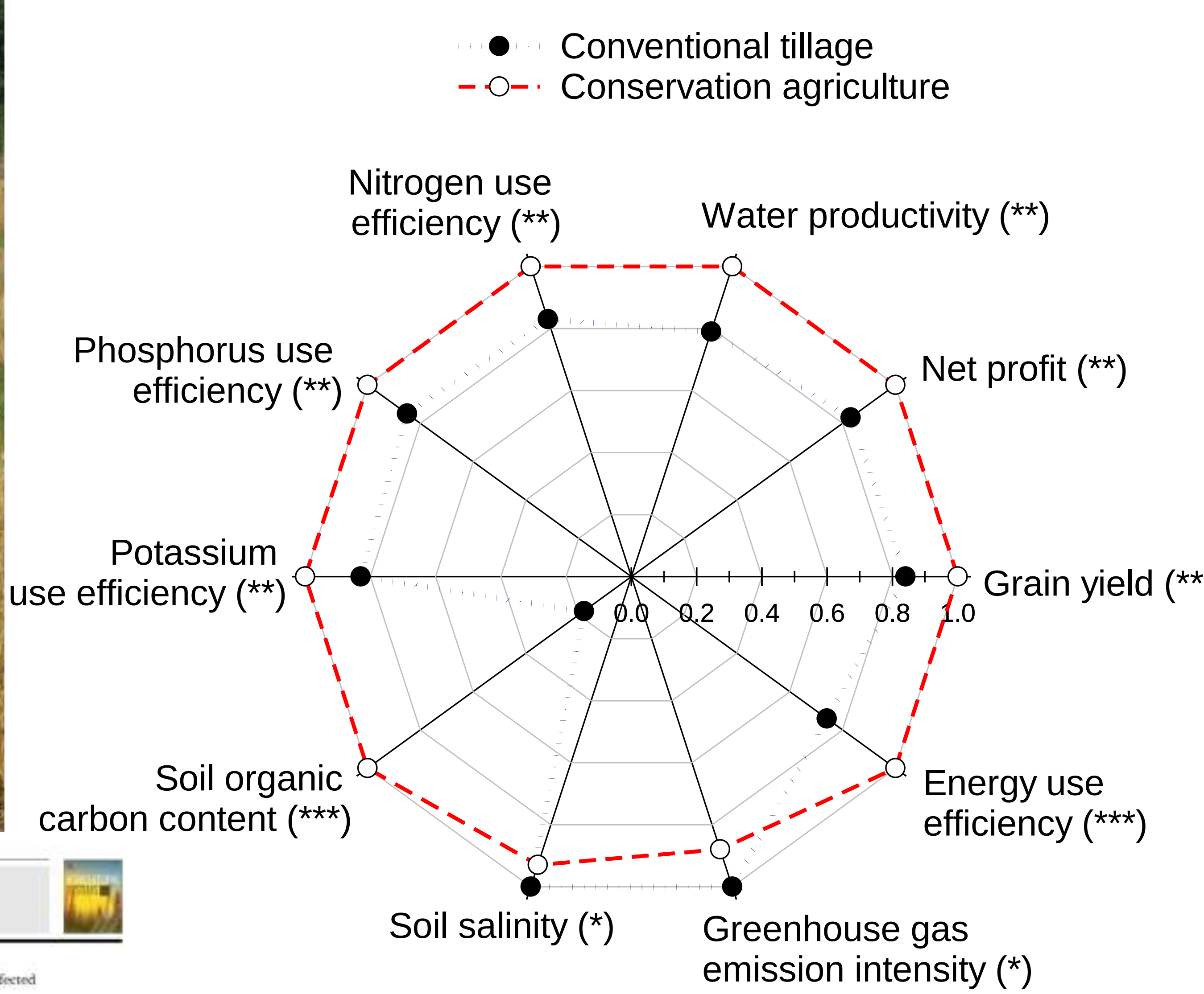
Water productivity (+26%)

Net profit (+20%)

EUE (+36%%)

GHGI (-14%)

Soil salinity (-7%)



Agricultural Systems

Managing salinity for sustainable agricultural production in salt-affected soils of irrigated drylands

Krishna Prasad Devkota, Mina Devkota, Meisam Rezaei, Roland Oosterbaan

CROP RESIDUE AS A MULCH UNDER CONSERVATION AGRICULTURE

Residue management is key for success of CA in dry lands

Wheat: Without residue retention

With residue retention

Forage mixture Without residue retention

With residue retention

Tillage method + organic amendment: long term experiment: Tel Hadya, Syria

ICARDA's long-term experiment in Tel Hadya, Syria, on an alkaline, very fine clay soil to examine the influence of tillage method and crop-residue management options with & without compost addition on soil properties & crop yields.

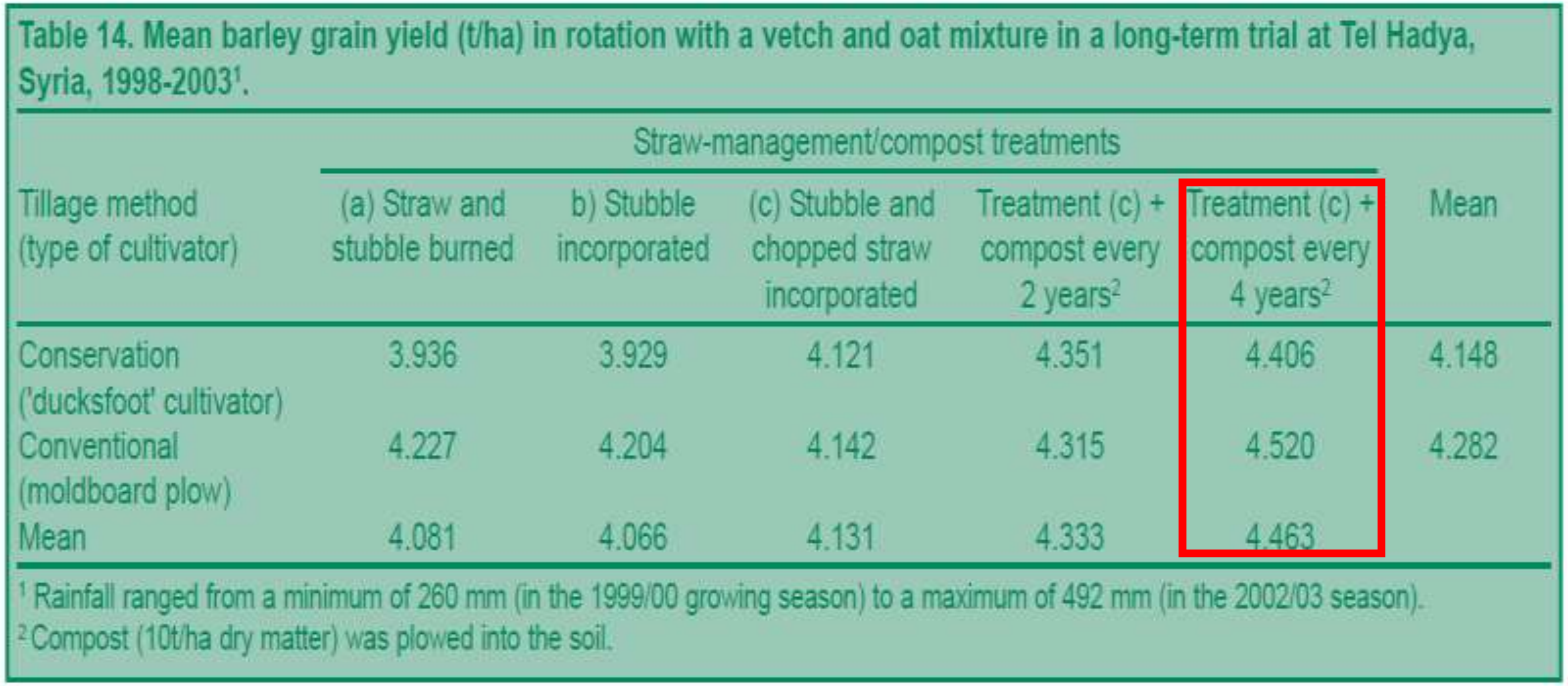


Table 14. Mean barley grain yield (t/ha) in rotation with a vetch and oat mixture in a long-term trial at Tel Hadya, Syria, 1998-2003[1].

Tillage method (type of cultivator)	Straw-management/compost treatments					Mean
	(a) Straw and stubble burned	b) Stubble incorporated	(c) Stubble and chopped straw incorporated	Treatment (c) + compost every 2 years[2]	Treatment (c) + compost every 4 years[2]	
Conservation ('ducksfoot' cultivator)	3.936	3.929	4.121	4.351	4.406	4.148
Conventional (moldboard plow)	4.227	4.204	4.142	4.315	4.520	4.282
Mean	4.081	4.066	4.131	4.333	4.463	

[1] Rainfall ranged from a minimum of 260 mm (in the 1999/00 growing season) to a maximum of 492 mm (in the 2002/03 season).

[2] Compost (10t/ha dry matter) was plowed into the soil.

Tillage treatments in the long-term trial at ICARDA.

ICARDA Annual report, 2003

The study from Tunisia found that adoption of CA enhances wheat yield by 15%, WUE by 13-18%, SOC accumulation by 0.13 - 0.18 t ha^{-1} year^{-1} & reduction of 1.7 - 4.6 t ha^{-1} year^{-1} of soil loss due to erosion by water compared to CT under both semi-arid and sub-humid conditions (Bahari et al. 2019)

ORGANIC AMENDMENTS: PHOSPHOGYPSUM IN CENTRAL ASIA- HIGH MAGNESIUM SOIL

- Phosphogypsum is a coproduct of the production of fertilizer from phosphate rock.
- Approximately 4-6 tons of PG is produced per ton of phosphoric acid production.
- Globally, 250-300 million t of PG is produced per annum, and out of the this ~ 85% coproduct is still discarded into ocean or stored in ponds or heaps without purification, causing several environmental degradations (Pereira et al., 2021).

Participatory on-farm experiment was conducted in Arys Turkestan, Kazakhastan for 4 years in 3 ha

- Effects of different rates of PG application on chemical changes in a high Mg+2 soil
- Observe response of cotton to PG application
- To understand the economic benefit of the PG application rate

Arys Turkestan canal command area

ORGANIC AMENDMENTS: PHOSPHOGYPSUM IN CENTRAL ASIA- HIGH MAGNESIUM SOIL

Three different treatments

1. Control (without PG)
2. Soil application of @ 4.5 t/ha PG
3. Soil application of @ 8 t/ha PG

PG was applied once at beginning of the experiment

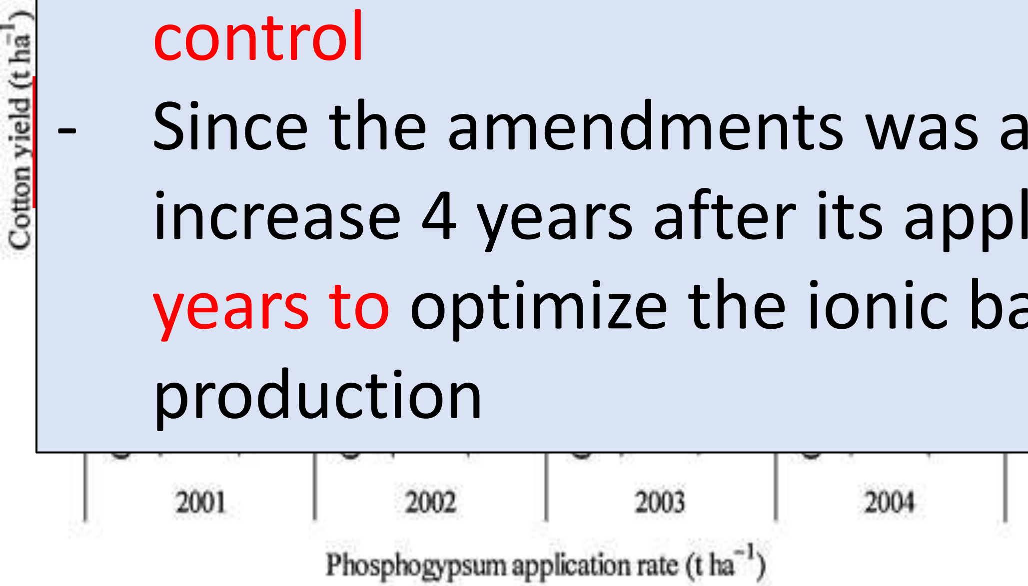
Cotton field without PG applicat

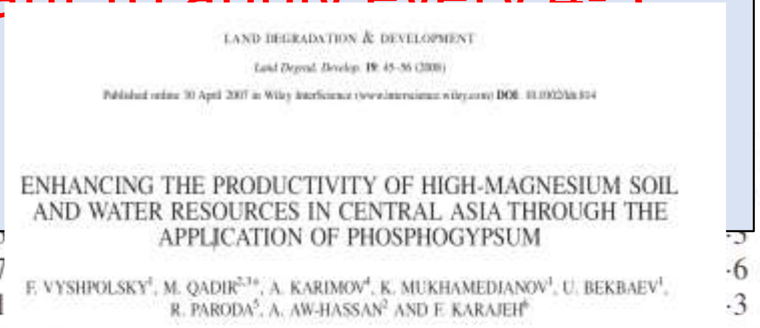
Cotton field with PG application

Table VIII. Economic evaluation of phosphogypsum application at 0, 4·5, and 8·0 t ha^{-1} during different years (expressed in

Total cost
Gross income 477 ·6
Net income 251 ·3

- The economic benefits from PG treatments were almost twice those from control
- Since the amendments was applied once in the beginning Mg levels tended to increase 4 years after its application, it may be important to apply every 4-5 years to optimize the ionic balance and sustain higher production





LAND DEGRADATION & DEVELOPMENT

Land Degrad. Develop. 19: 45–56 (2008)

Published online 30 April 2007 in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/ldr.814

ENHANCING THE PRODUCTIVITY OF HIGH-MAGNESIUM SOIL AND WATER RESOURCES IN CENTRAL ASIA THROUGH THE APPLICATION OF PHOSPHOGYPSUM

F. VYSHPOLSKY[1], M. QADIR[2,3*], A. KARIMOV[4], K. MUKHAMEDIANOV[1], U. BEKBAEV[1], R. PARODA[5], A. AW-HASSAN[2] AND F. KARAJEH[6]

ORGANIC AMENDMENTS: PHOSPHOGYPSUM IN FOR DIFFERENT CROP IN CENTRAL ASIA

- PG increased wheat and cotton productivity, increases **infiltration rates** saving irrigation water by 15-25%, and increased farmers' income.
- PG increased productivity of melon, silage corn, grain corn, winter wheat, and sunflower
- Result also showed improves **soil quality and soil fertility**, increases the **calcium and phosphorus** content, enhances **crop growth and development.**

- ➢ Applying the phosphogypsum without proper assessment of soil quality could lead to excessive or inadequate rates.
- ➢ Applying the PG below the actual requirements only partially improves the soil, while the excessive application has economic consequences for farmers.
- ➢ Therefore, rates should be aimed at the soil improvement (physical and chemical properties).

EFFECT OF MINERAL, ORGANIC & BIO-FERTILIZERS ON WHEAT YIELD AND QUALITY IN EGYPT

Clay loam soil
pH: 7.90
EC[ds/m]: 1.74
Organic matter (%): 1.75

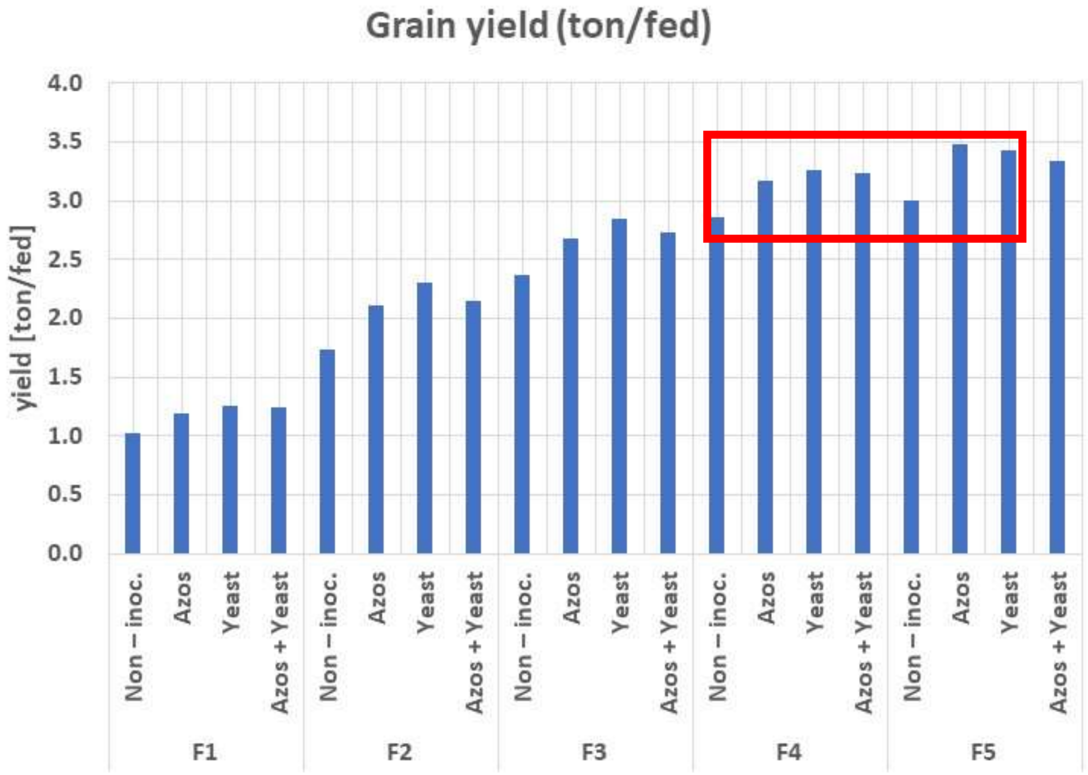
Mineral and organic fertilizers :

1. **[F1]** 100 % Organic Fertilizer (8 ton/fed compost from solid waste)
2. **[F2]** 25 % Mineral Fertilizers + 75 % Organic Fertilizer
3. **[F3]** 50 % Mineral Fertilizers + 50 % Organic Fertilizer
4. **[F4]** 75 % Mineral Fertilizers + 25 % Organic Fertilizer
5. **[F5]** 100 % Mineral Fertilizers (225, 150, 50 kg/fed of NPK)

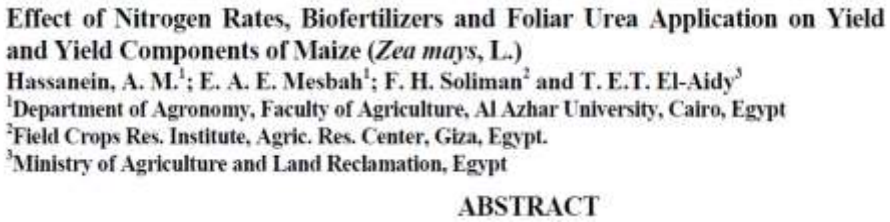
Biofertilizers:

1. **[Non – inoc.]** Without inoculation (control)
2. **[Azos] -** Azospirillum brasilense (Azos.) (7.2 X 106 cell/ml)
3. **[Yeast] -** soil yeast (Candida tropicales) (yeast) (Gomaa, 1995)
4. **[Azos. + yeast.]**

- Highest yield was obtained with F4 and F5 with bio-fertilizer.
- Similar trend was obtained for grain protein content



Hassanein et al., 2019



Effect of Nitrogen Rates, Biofertilizers and Foliar Urea Application on Yield and Yield Components of Maize (*Zea mays*, L.)

Hassanein, A. M.[1]; E. A. E. Mesbah[1]; F. H. Soliman[2] and T. E.T. El-Aidy[3]

[1]Department of Agronomy, Faculty of Agriculture, Al Azhar University, Cairo, Egypt
[2]Field Crops Res. Institute, Agric. Res. Center, Giza, Egypt.
[3]Ministry of Agriculture and Land Reclamation, Egypt

ABSTRACT

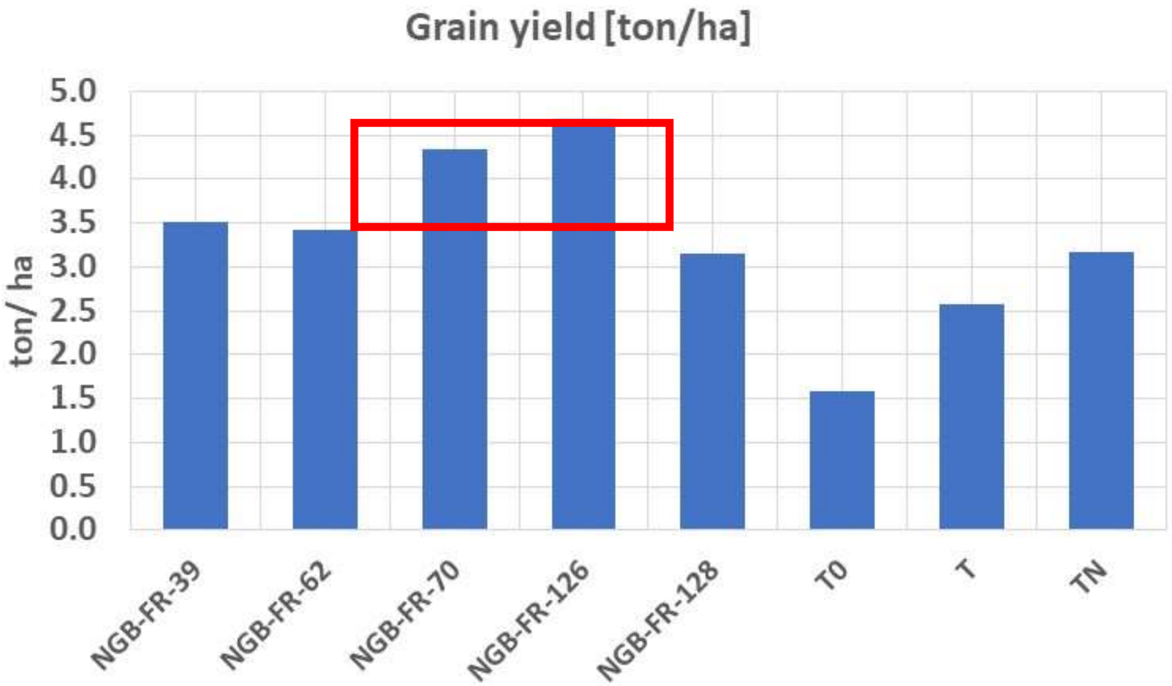
2 . Improvement of faba bean yield using Rhizobium/Agrobacterium inoculant in low-fertility sandy soil in Egypt

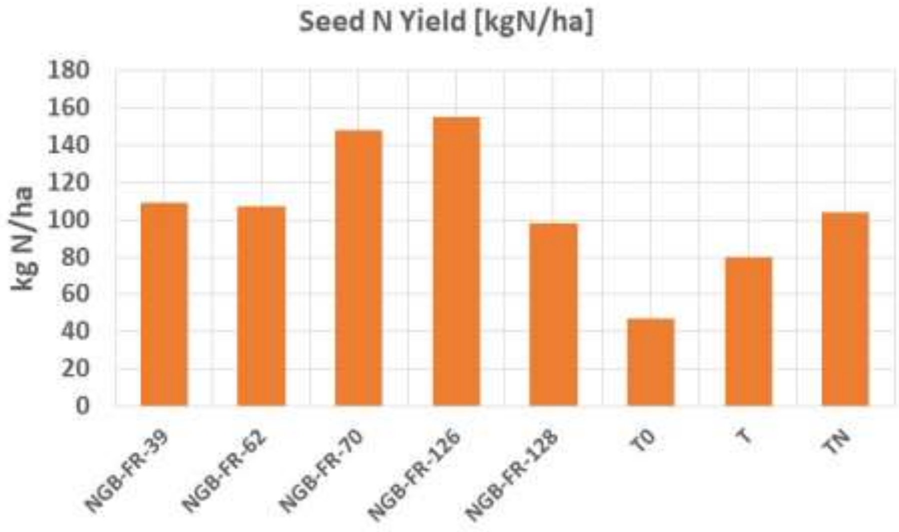
Variety: Giza 843
Soil type: Sandy
pH: 7.94; EC [ds/m]: 0.81
Organic matter (%): 0.30

Rhizobial strains: (+ 48 kg N/ha as a starter N-dose)

- **NGB-FR 39:** A. tumefaciens
- **NGB-FR 62:** A. tumefaciens
- **NGB-FR 70:** R. leguminosarum sv. Viciae
- **NGB-FR 126:** R. leguminosarum sv. Viciae
- **NGB-FR 128:** R. leguminosarum sv. Viciae

T0: uninoculated seeds with out N-fertilizers.
T: uninoculated seeds + starter N-fertilizer (48 kg N·ha^{-1})
TN: uninoculated seeds + full N-fertilizer (96 kg N·ha^{-1})





- Significant yield increased with Rhizobium inoculation
- Similar trend was obtained for grain protein content

Source: Youseif, et al., 2017

FEASIBILITY AND TECHNICAL STUDY FOR ESTABLISHING RECYCLING DATE PALM BY-PRODUCT TO PRODUCE ORGANIC FERTILIZERS

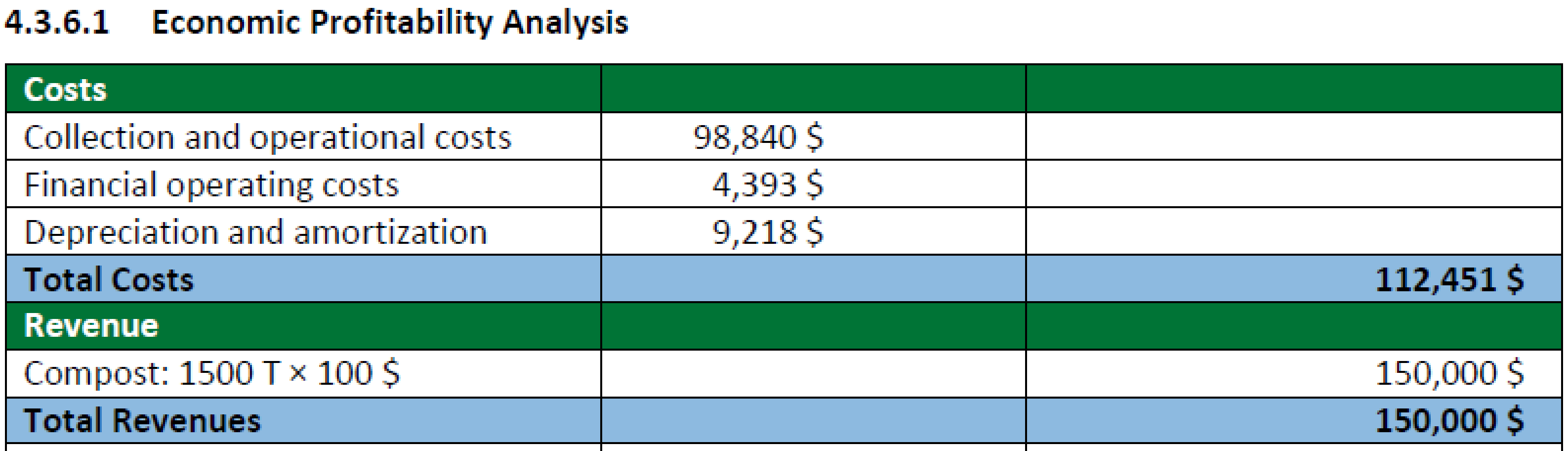
Date palm production is a strategic sector in most of the Arab countries. The sector is one of the oldest economic activity to play a crucial role in the welfare, culture, history environment, and nutrition of its population. The Region is the world leader of date cultivation with almost 75% of the global area under a date palm, ~ 77% of world production & ~ 69% of total world export of dates (FAOSTAT).

ICARDA
Science for resilient livelihoods in dry areas

Feasibility and Technical Study for Establishing Recycling Date Palm by Product Unit (date palm waste) to Produce Organic Fertilizers (compost) in the GCC Countries

Developing Sustainable Production Systems for Date Palm in the Gulf Cooperation Council countries

The palm tree dates constitutes the pivot of the agriculture, offers a large agricultural by-product & date palm residues that could be used for many purposes (feeding of livestock, composting, etc.). The estimation of the tonnage of date palm grove waste in the GCC countries vary between 7734.4 tons in Qatar to 121974.4 in the UAE (FAOSTAT).



4.3.6.1 Economic Profitability Analysis

Costs		
Collection and operational costs	98,840 $	
Financial operating costs	4,393 $	
Depreciation and amortization	9,218 $	
Total Costs		**112,451 $**
Revenue		
Compost: 1500 T × 100 $		150,000 $
Total Revenues		**150,000 $**

The economic and financial indicators reveal profitability of implementing this kind of project in the GCC countries.

SUMMARY

Use of soil amendments help for ecosystem restoration process in degraded drylands

Not all technologies fit in a different environments. It is important to access the socio-technical feasibility of the innovations before deciding to implement in the real field

Risk arising from the application

- Excess of soluble salts and sodium (Guerrero et al. 2007)
- Poor organic matter stabilization (Garci-Gomez et al. 2005)
- Excessive nitrogen mineralization (Hueso Ginzakez et al, 2015)
- Pathogenic agents (Garcia-Orenes et al. 2007)
- Presence of no-native species and seeds (Hueso Gonzalez et al. 2016
- Nitrophylous species appearance (Hueso Gonzalez et al. 2015)
- Heavy metals (Guerrero et al., 2007)

Thank You

Current condition: degraded rangeland

Land degradation is a long – term loss of ecosystem services

The Solution is RESTORATION

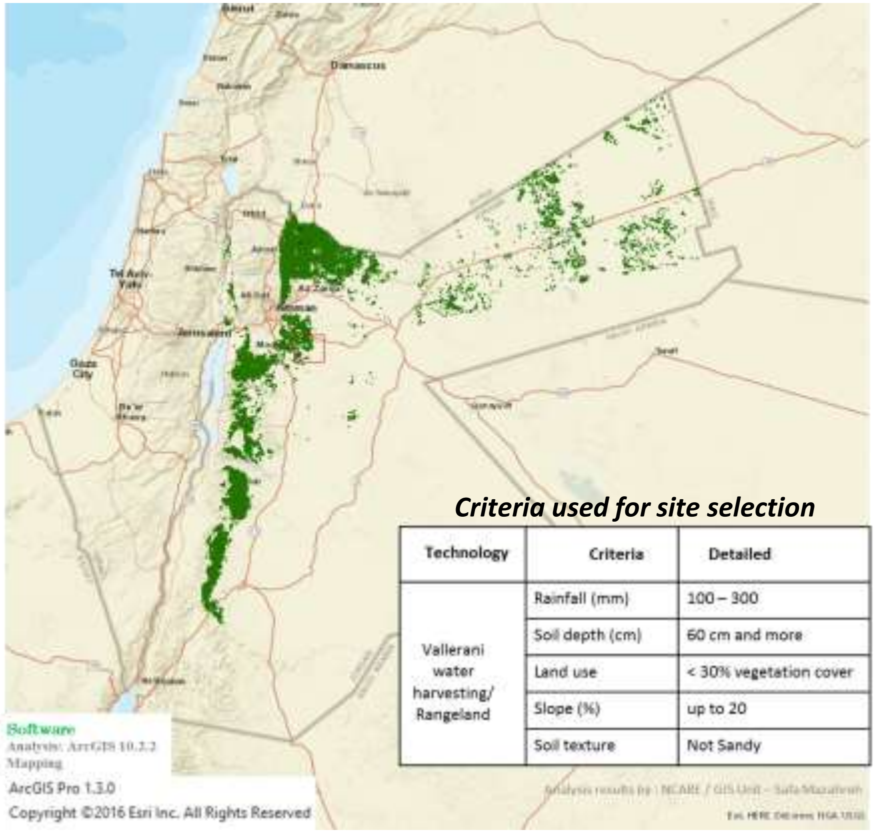
Restoration means to reproduce the ecosystem structure and functioning that existed.

It is a simulation of the original ecosystem before disturbance.

The mechanized micro-Water Harvesting is one of the restoration techniques.
This technique suitable for large scale implementation but limited to certain areas and conditions




Rangeland restoration in Jordan: restoring vegetation cover by water harvesting measures



Criteria used for site selection

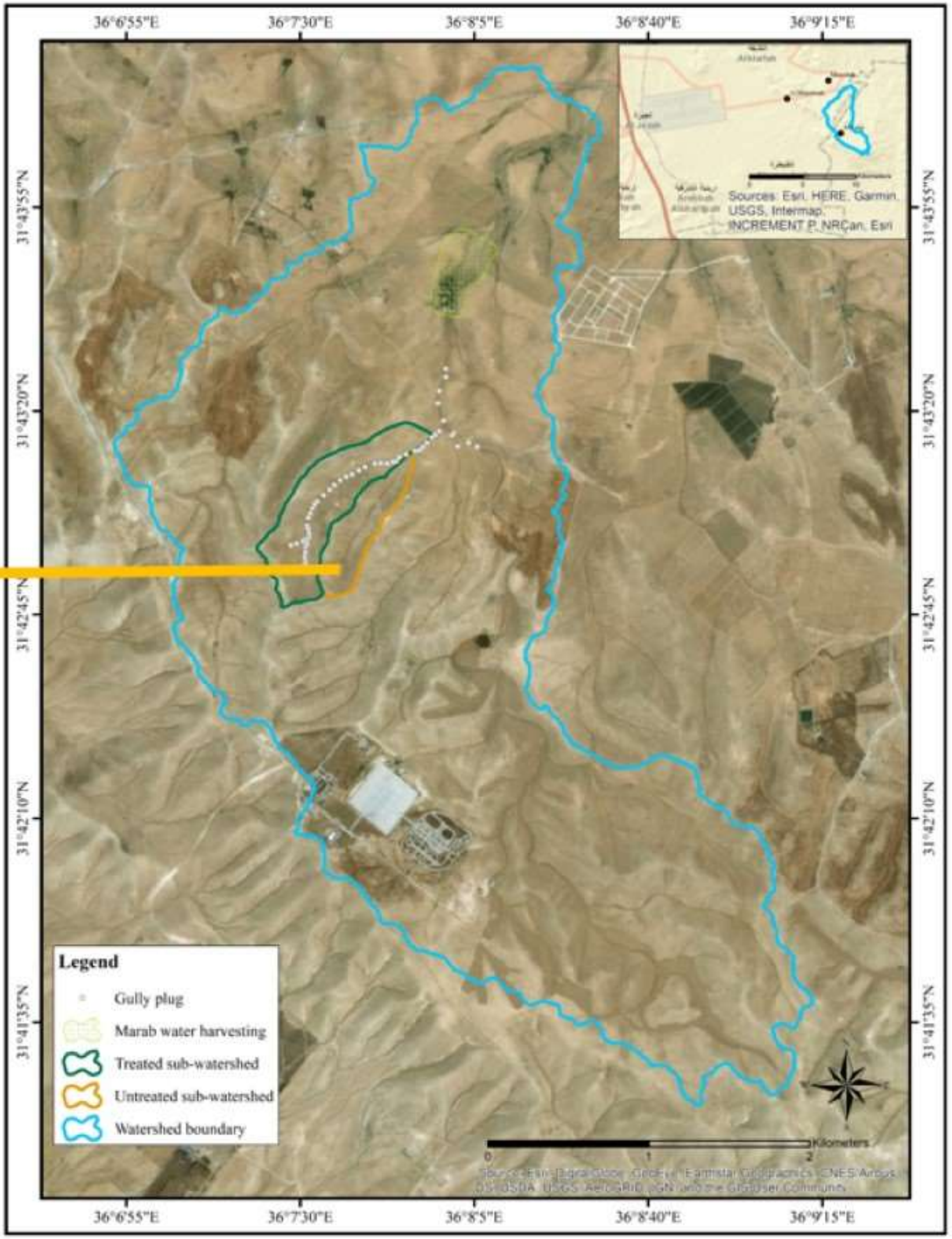
Technology	Criteria	Detailed
Vallerani water harvesting/ Rangeland	Rainfall (mm)	100 – 300
	Soil depth (cm)	60 cm and more
	Land use	< 30% vegetation cover
	Slope (%)	up to 20
	Soil texture	Not Sandy


A. Baseline


B. Degraded


C. Restored

Up-stream areas – no treatment
Normal land use – Barely agriculture and grazing



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri

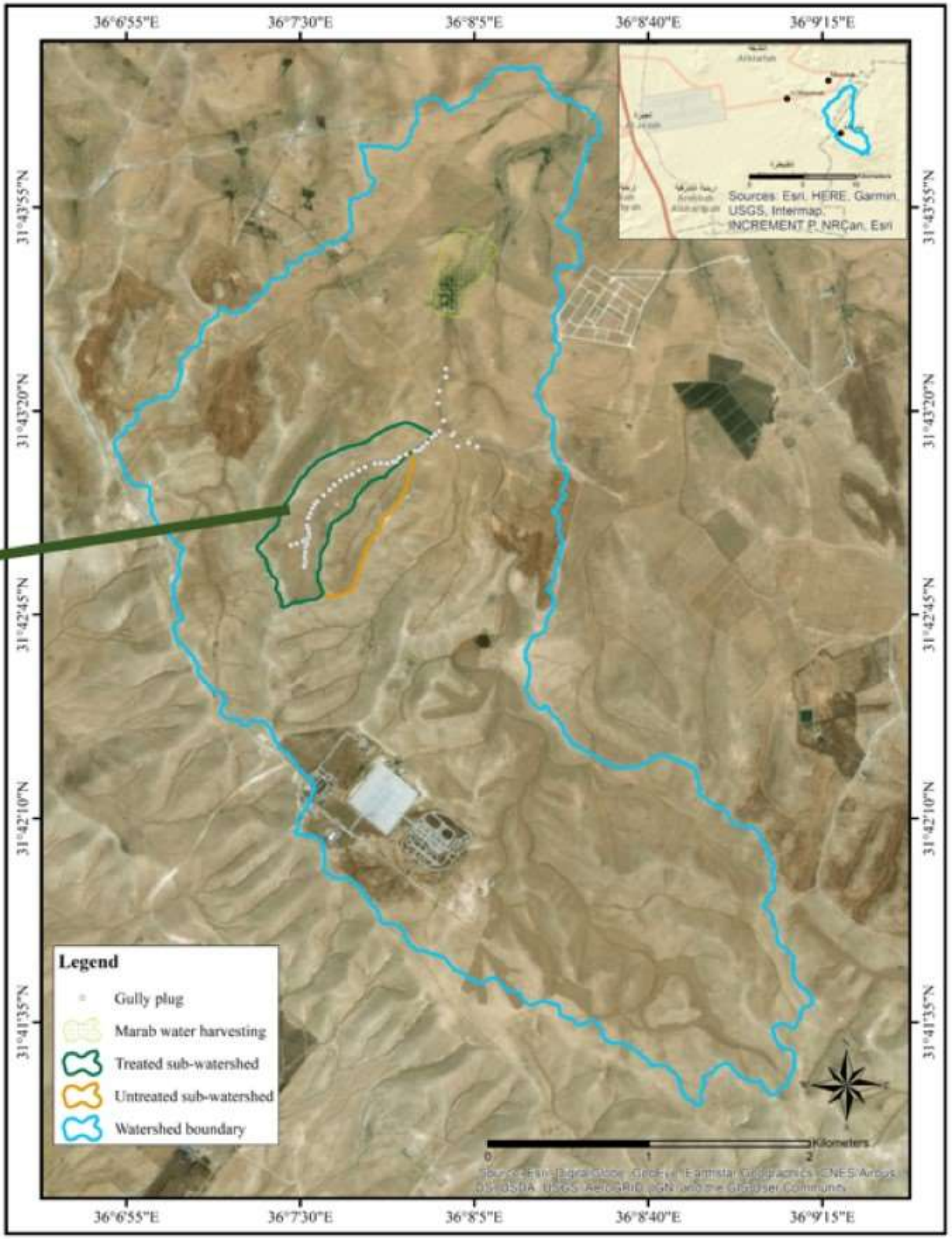
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Up-stream areas – restoration
Soil and water conservation method and out-planting of native rangeland species

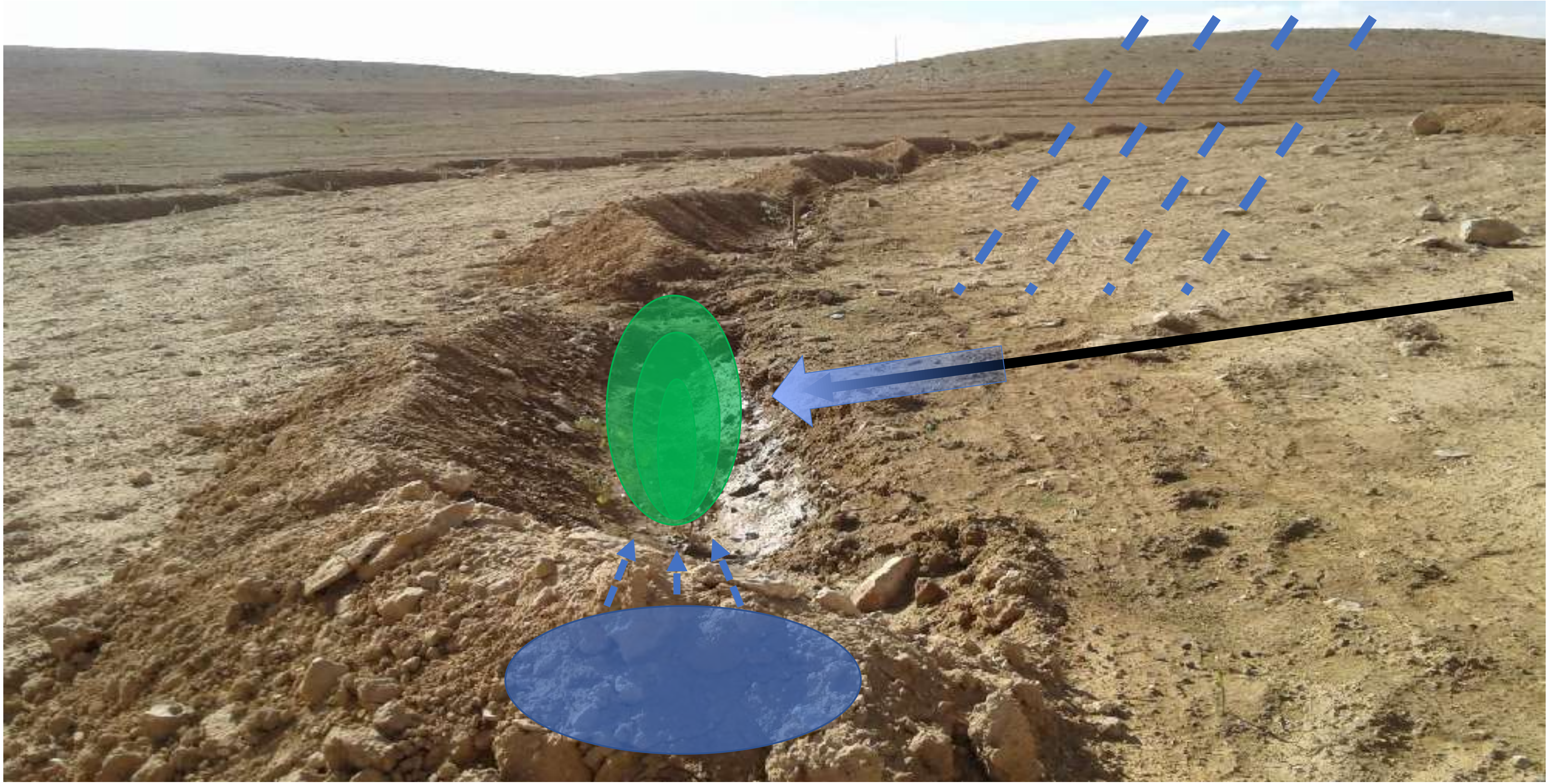
December 2016

February 2017

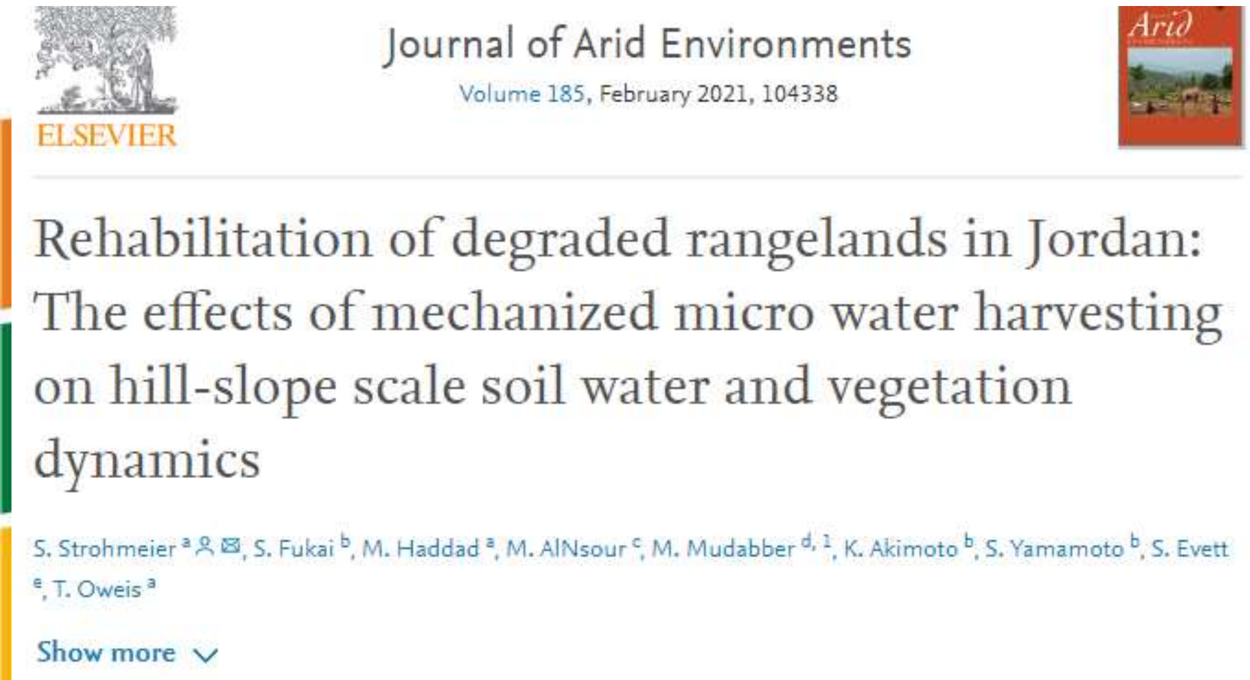
March 2020



Micro Water harvesting



Micro Water harvesting



Journal of Arid Environments
Volume 185, February 2021, 104338

Rehabilitation of degraded rangelands in Jordan: The effects of mechanized micro water harvesting on hill-slope scale soil water and vegetation dynamics

S. Strohmeier [a], S. Fukai [b], M. Haddad [a], M. AlNsour [c], M. Mudabber [d, 1], K. Akimoto [b], S. Yamamoto [b], S. Evett [e], T. Oweis [a]

International Soil and Water Conservation Research
Volume 10, Issue 4, December 2022, Pages 610-622

Original Research Article

Rangeland restoration in Jordan: Restoring vegetation cover by water harvesting measures

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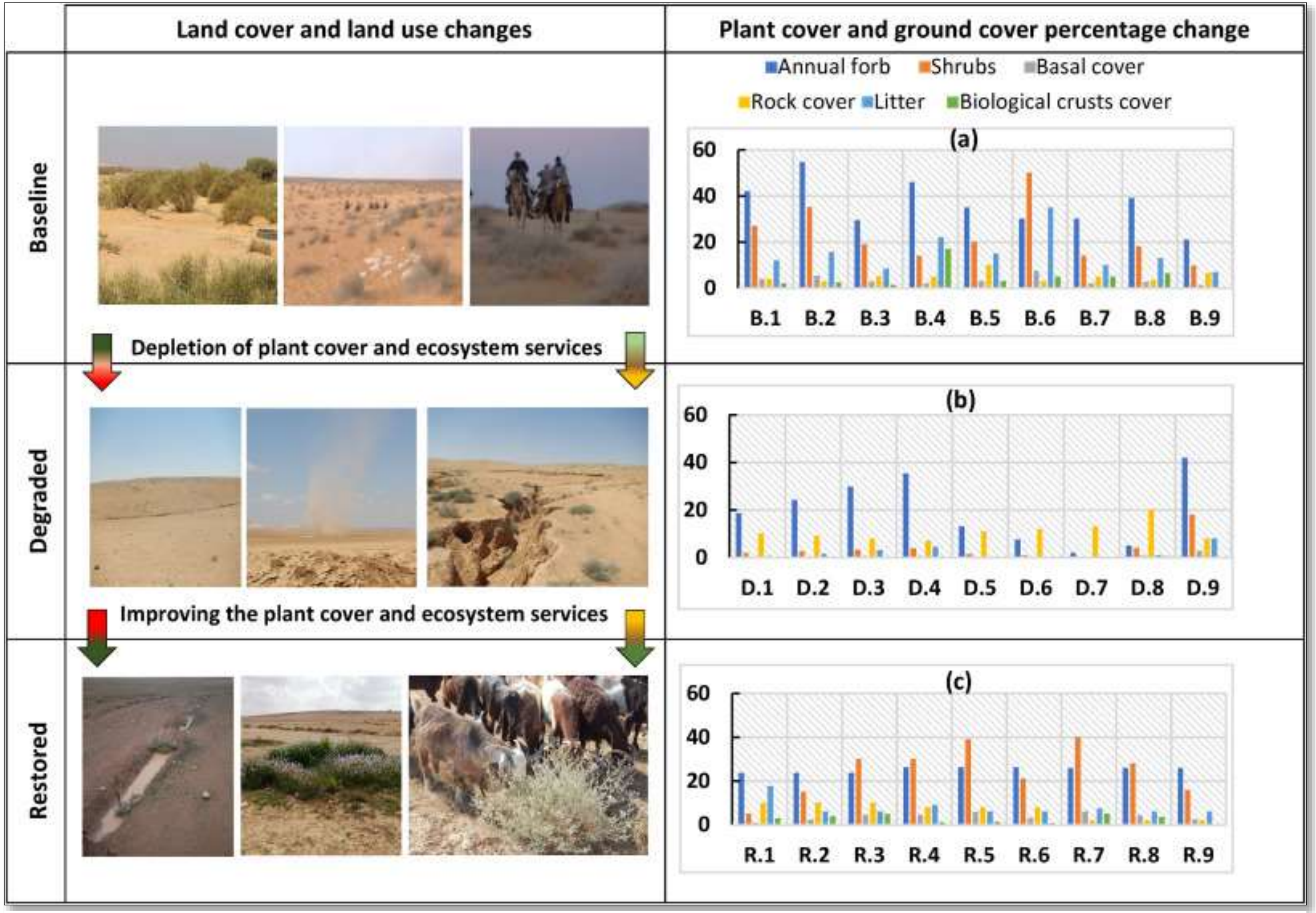
Evidence-based and scientifically proven technology

Rangeland restoration in Jordan: Restoring vegetation cover by water harvesting measures



Schematic diagram of the different model states and the transition of hillslope areas in the Jordan Badia (left) and plant cover changes (%) for the annual herbs, shrubs and basal cover, and ground cover changes (%) for the rock cover, litter and biological crust cover developed for (a) baseline scenarios, (b) degraded scenarios, and (c) restored scenarios (right).

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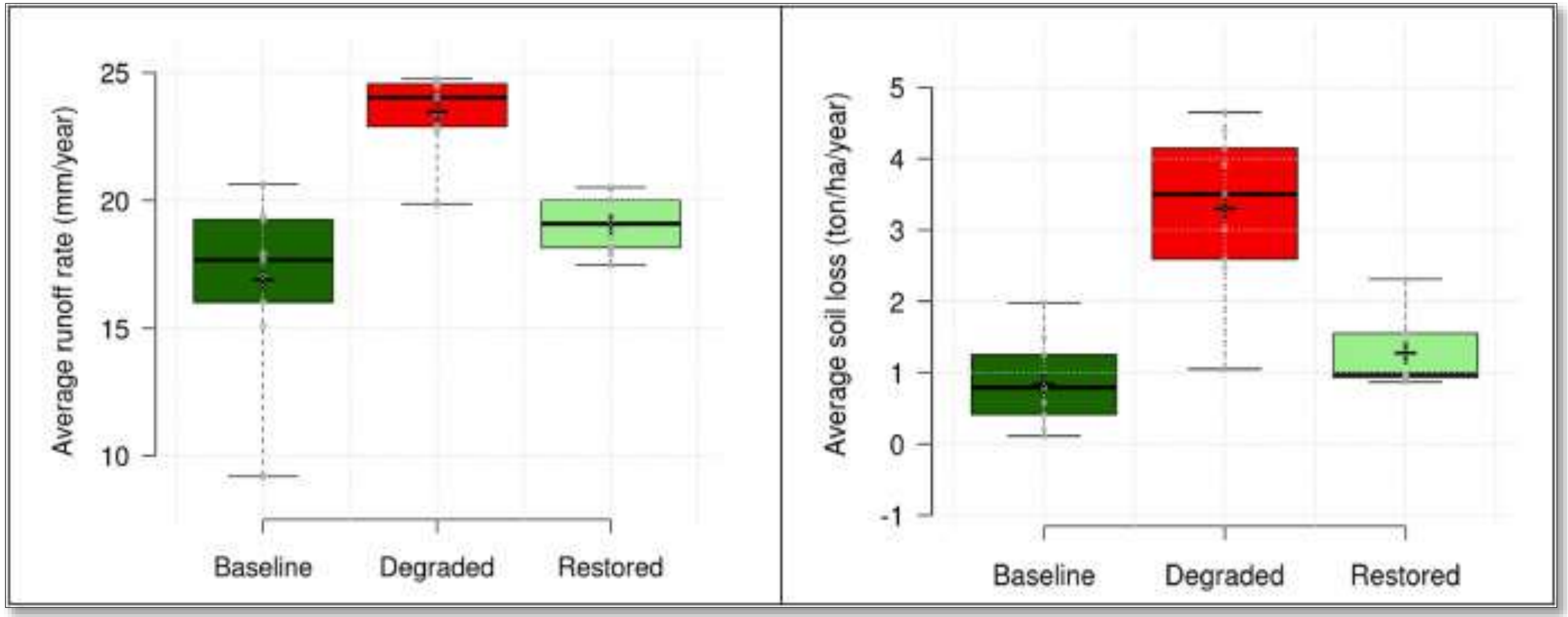

Results of the tested rangeland scenarios state: the average soil loss (ton/ha/year) (left Box Plots) and the average runoff rate (mm/year) (right Box Plots).

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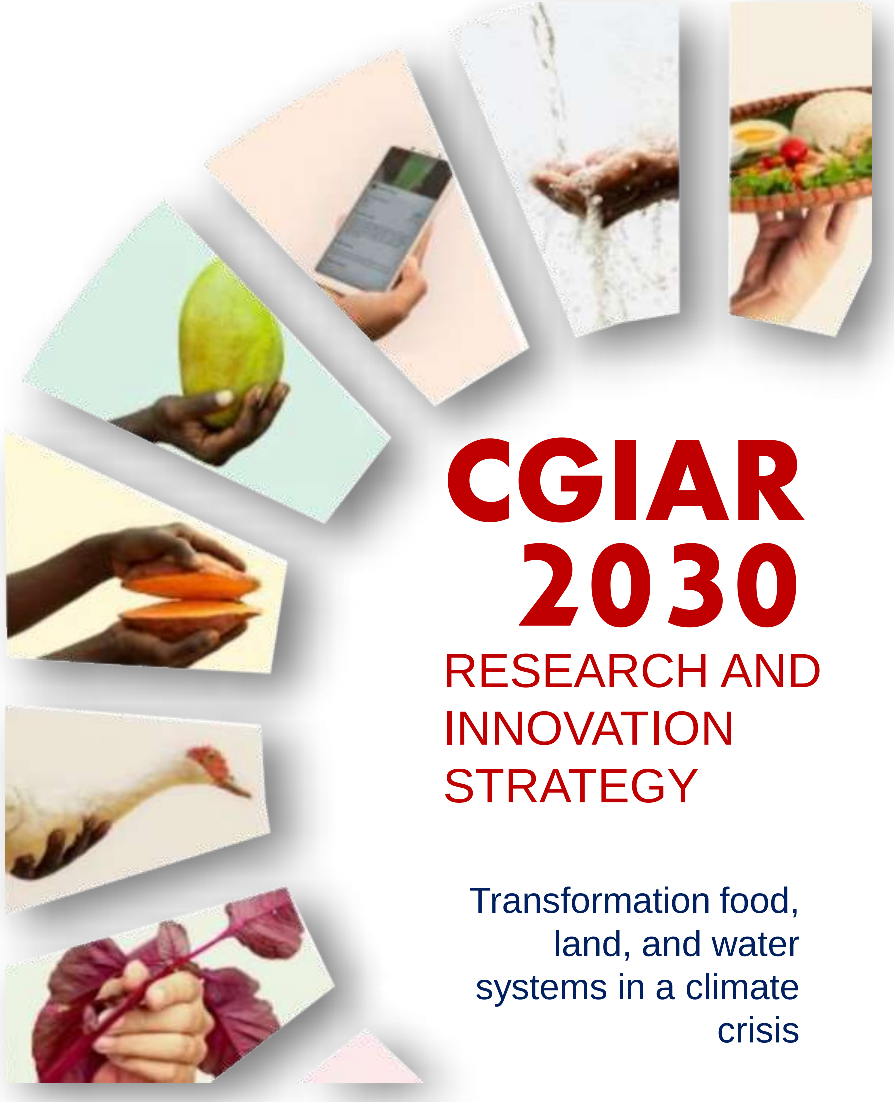

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Transformation food, land, and water systems in a climate crisis

Thank You