Role of Integrated Farming System for Regenerative Agriculture in Drylands

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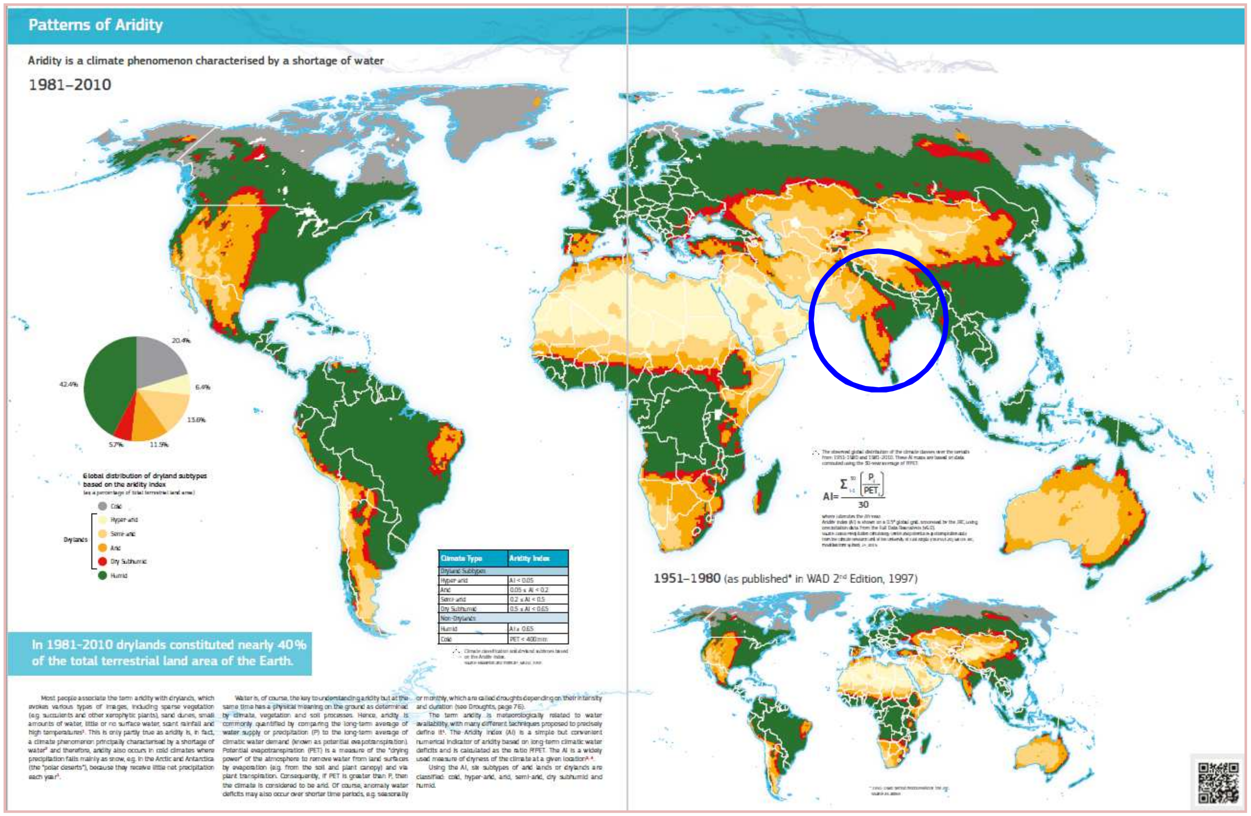
Brainstorming Session (26 June, 2021)

Regenerative Agriculture for Soil Health, Food and Environmental Security

Drylands on the Earth and Indian Dryland Agriculture



- About <u>41% of land area is drylands</u>
- Within drylands
  - <u>**42% is arid**</u>
  - 37% is semi-arid
  - 21% dry sub-humid

- Created a <u>large irrigation potential (</u>surface and groundwater resources)
- Indian agriculture is still predominantly <u>rainfed covering about 55%</u> of the net sown area
- Accounts for <u>40% of the total food production</u>
- Even after full exploitation of irrigation potential, almost <u>half of the net sown area is estimated to remain rainfed</u>.
- <u>Challenges</u> in drylands will <u>intensify</u> in future in view of climate change

The guiding principle - IFS

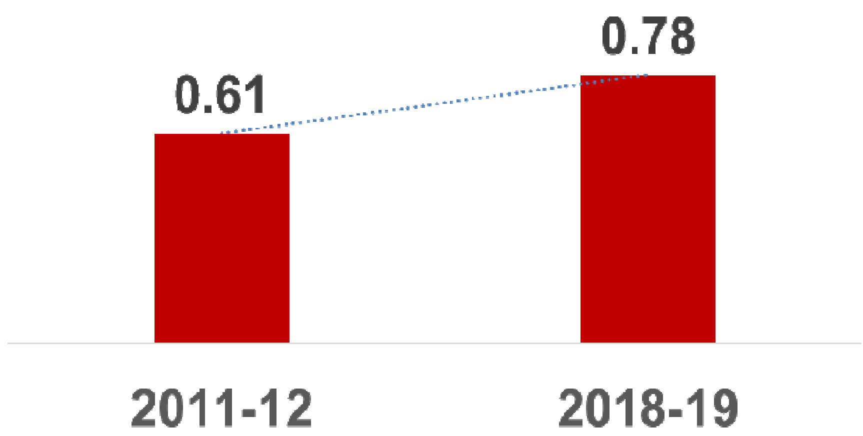
- Combination of crops (annuals + perennials), livestock and related subsidiary enterprises
- An interdependent, interrelated and often interlocking production system
- Maximize the utilization of output/nutrients from one component to other components
- Minimize the negative effect of enterprises on environment

RA & IFS

- Soil organic matter
- Soil biodiversity
- Carbon-sequestration to reverse the climate change
- Productivity, diversification, resilience, income, risk aversion, livelihood

Improvement in SOC due to IFS

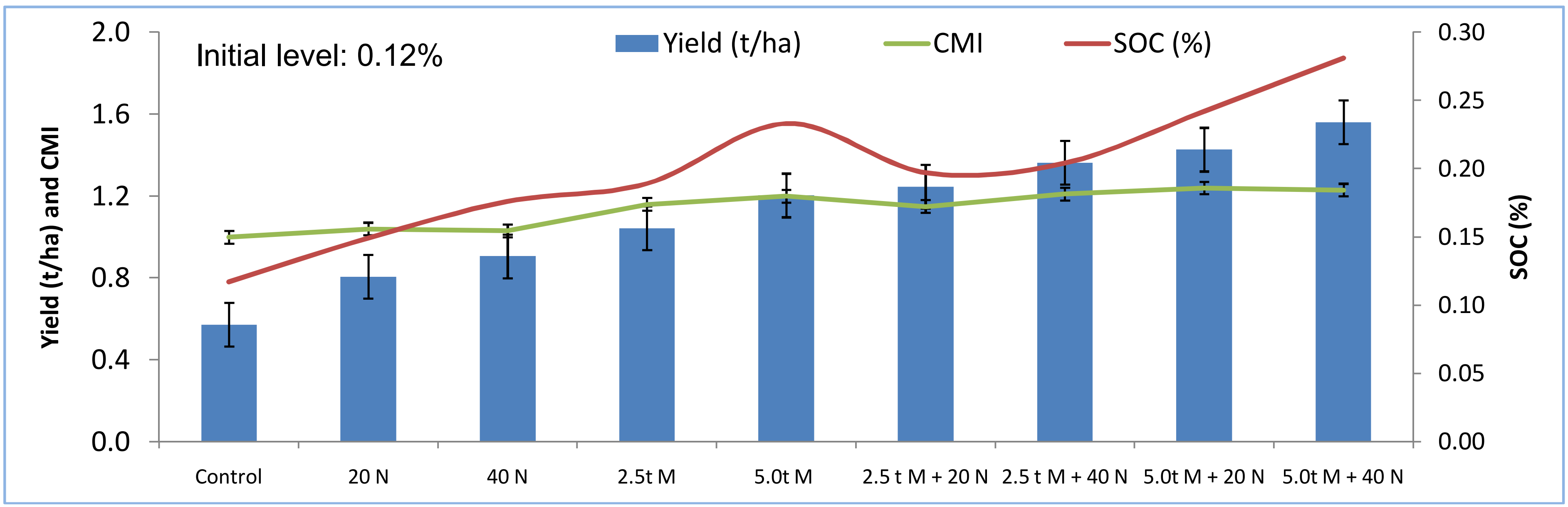
Soil Organic Carbon (%) (n=31 models)



- Low to Medium SoC : 3 models
- Medium to High SoC: 5 models
- 285 improvement in soil organic carbon: 20.8 to 39.3 % at different locations.
- Significant improvement was observed due to recycling of wastes from livestock, using of crop residues as mulching and leaf litter from boundary plantations.

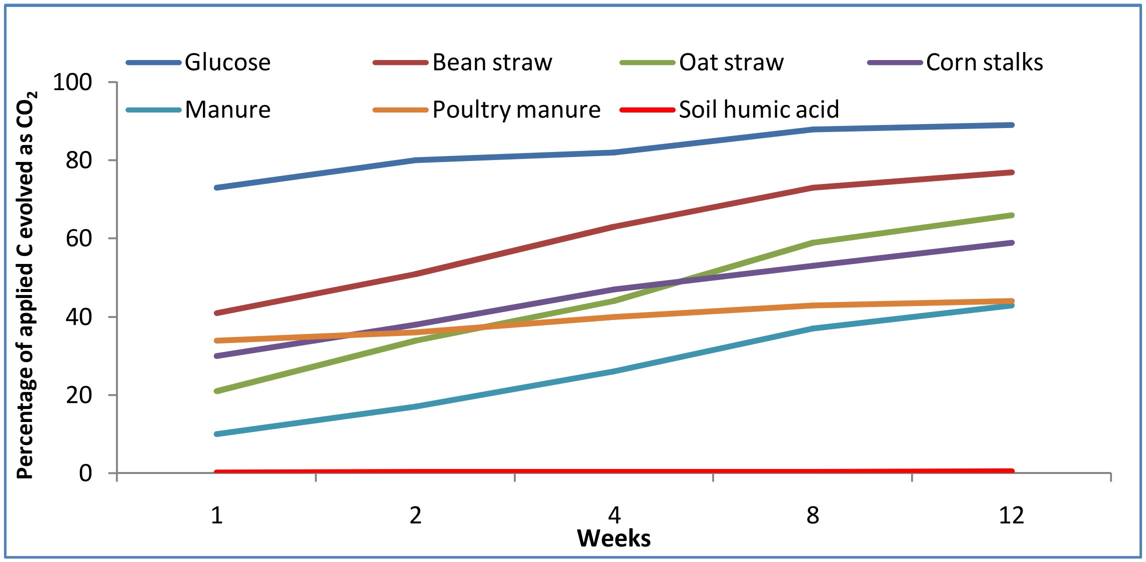
Soil Organic Carbon and Carbon Management Index in long-term FYM expt.

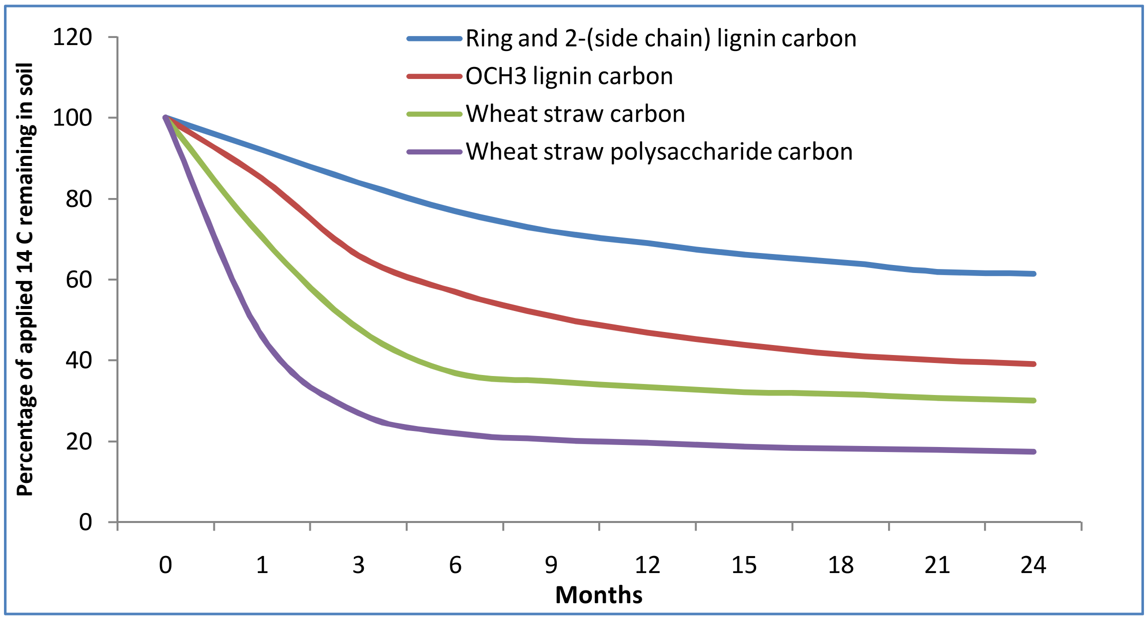
- Long term application of organic manure leads to increase in 0.16% of organic carbon in arid soil after continuous application of organic manure for 25 year
- Increased carbon is not stable one, after discontinuing the application it starts decreasing due to increased decomposition due to prevailing climatic conditions in arid region. As the C turnover time for new humus is about 5-35 years only
- Carbon management index (CMI) was markedly greater in all the INM treatments than that of inorganic fertilizer treatments which clearly indicate positive effect of organic manure in soil management



Treatments (M: Manure; N: Nitrogen through Urea)

Organic matter decomposition and retention in arid soils

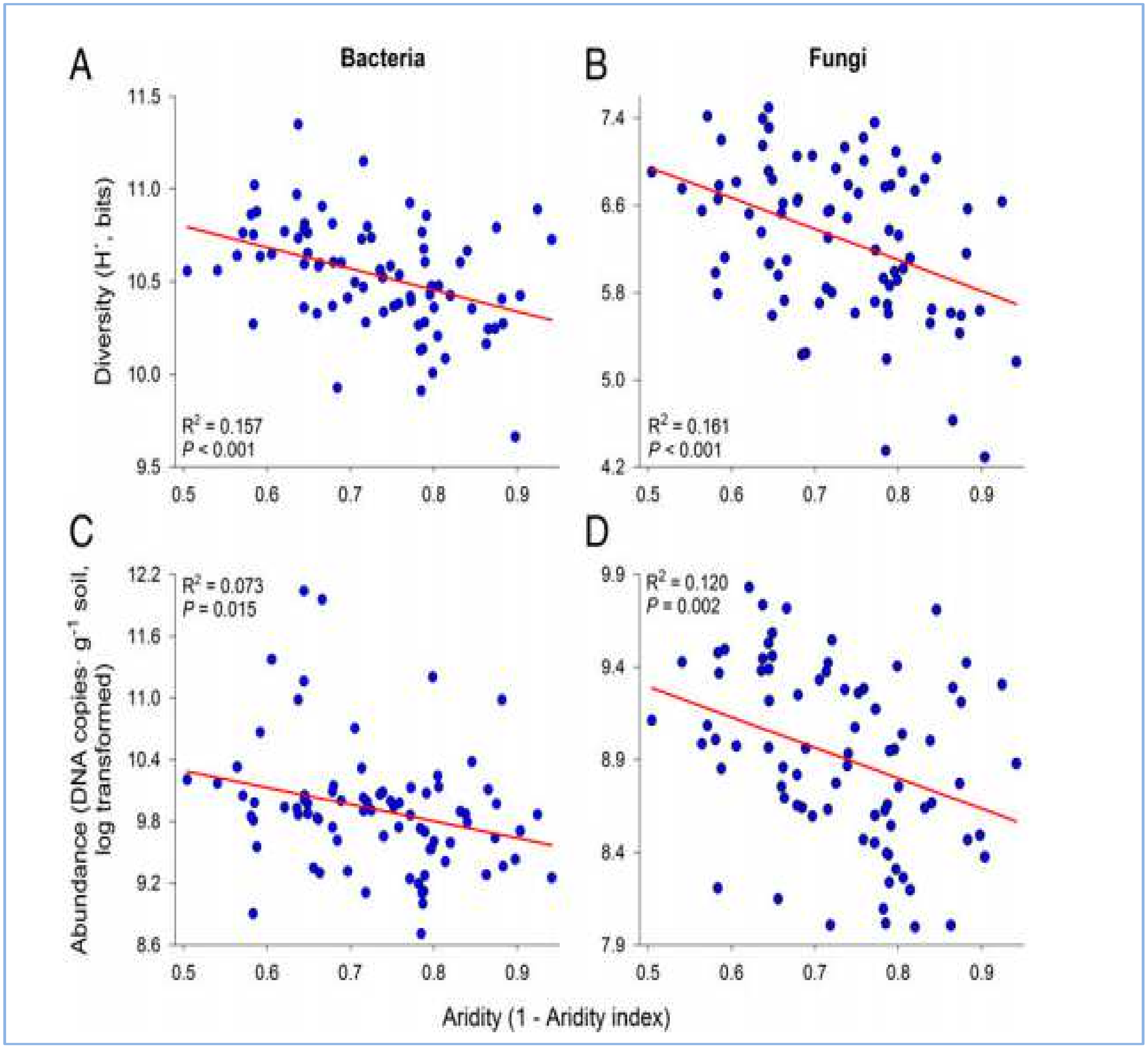




- <u>Generally after 1 year about 55 to 70% of the C of most crop residues and leaves will have evolved as CO_2.</u> About 5 to 15% of the residual C will be present in soil biomass, and 85 to 95% in new humus.
- 67 to 69% of ^{14}C-labeled wheat straw and cornstalk carbons had evolved as CO_2 after 1 year
- Most of the soil and climatic factors prevailing in arid soils are pertinent to organic matter biodegradation and humus formation

Stott and Martin 1989; 2009

Global drylands: Increasing aridity reduces soil microbial diversity and abundance

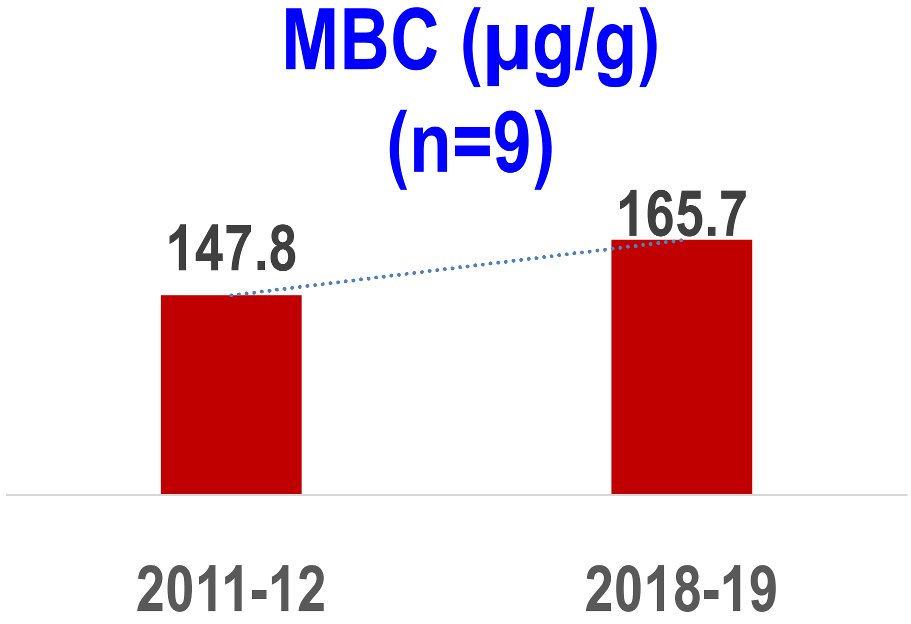


Increases in aridity are linearly associated with reductions in fungal and bacterial diversity and abundance

Maestre et al., 2015

Soil biodiversity in IFS models (n=16)

- Improvement in <u>fungal</u> population count ranged from 41.7 to 162.2 %
- <u>Bacterial</u> count: improvement ranged from 32.1 to 280 %
- <u>Actinomycetes</u> count improvement ranged from 25.8 to 70.1 %
- <u>Earthworm</u> count improvement: 32 %



Improvement in microbial population and biomass under different agri-silvi systems

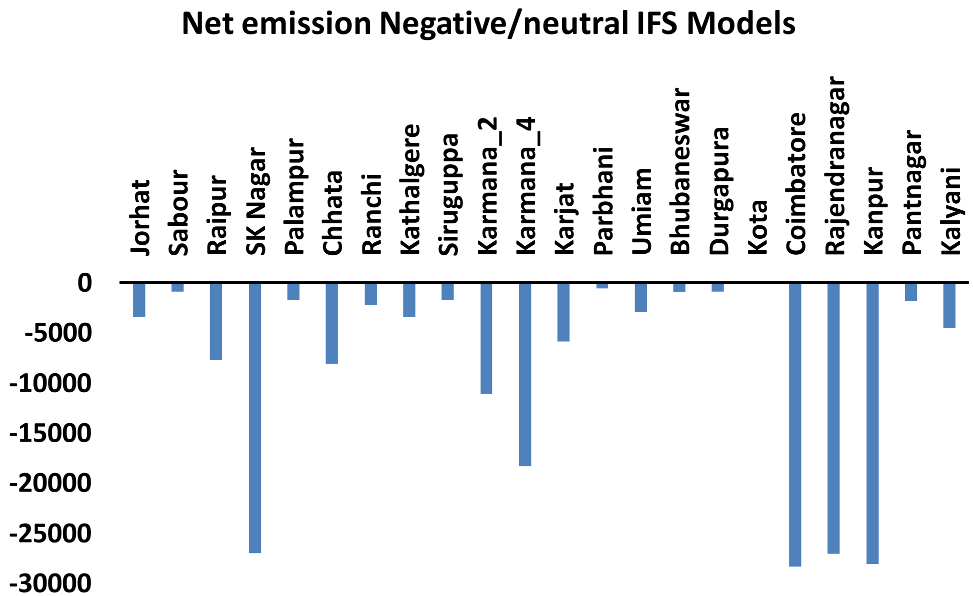
Silvi component	Increase over sole crop (%)			
	Fungi	Bacteria	Actinomycetes	Microbial biomass
Prosopis cineraria	13-24	21-37	9-18	18-23
Tecomella undulata	18-27	27-39	10-16	19-25
Ziziphus mauritiana	19-39	23-53	23-53	20-77

Substantial improvement in soil biological activities under agri-silviculture system compared to a sole crop

Yadav et al. (2011); Tarafdar (2008)

Carbon Neutrality of IFSs

Category	Number of IFS models	Net emission (kg CO_2 equivalent)
Net emission (negative / neutral)	22	-8478



- **Sink:** Orchard, boundary plantation, Agroforestry, and recycling
- **22 IFS models** offers scope for more intensification

Net GHG emission from IFS Model (CO_2-e in kg) in Semi-arid region

Enterprises	CO_2-e (kg)
Crops	32.2
Livestock	6215.5
Energy	420.2
Crop residue-incorporation	133.8
Fodder crops	15.3
Kitchen garden	0.03
Pesticide-Insecticide-Herbicide use	20.2
Total SOURCE	6837.1
Agro-Forestry- SINK	2169.6
Agro-Forestry- dbh-SINK	48.2
Total Biomass added - SINK	29199.6
Total SINK	31417.4
GHG-IFS	(-)24580.3

C sequestration over 19 years duration in different land use systems of arid zone (Mg C/ha)

Land use system	Soil C Stock after 19 years (initial C stock= 27.30)			Total C stock (Soil + Biomass)	C sequestration over 19 years	
	SOC	SIC	Total		Total	Rate (Mg C/ha/yr.)
Annual crops (Pearl millet-legume rotation)	9.27	19.03[a]	28.30	28.30	-1.00	-0.05
Agroforestry (*P. cineraria* + pearl millet-legume	10.33[a]	21.14	31.07[a]	40.27	10.97	0.58
Agri-Horticulture (Ber + pearl millet-legume)	11.49[a]	22.42	33.91	34.75a	5.45	0.29
Sole pasture (*Cenchrus ciliaris*)	10.37[a]	19.83[a]	29.62[a]	33.14a	5.30	0.28

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- Biomass in tree is the major source of C sequestration rather than soil under arid zone situation.
- Any amount if sequestered in soil in long term it is in the form of SIC.
- Annual cropping do not sequester C in soil. However, tree based systems improved the same to some extent.
- Singh *et al*. (2007) also reported that 27 years of pearl millet cropping in different soil types depleted SOC stock in the order Typic Torrisamments (19.7%) > Lithic Torripsamments > Typic Haplocambids (0.9%).

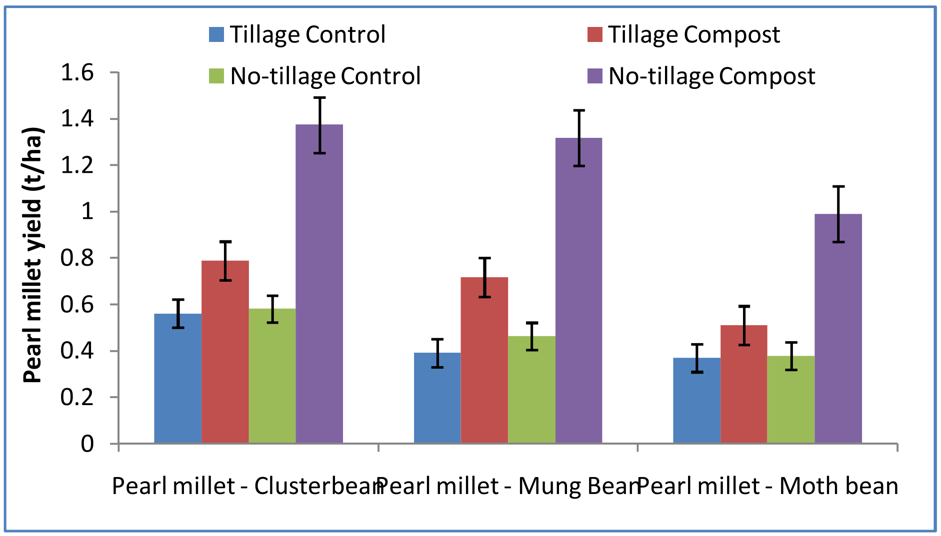
Root characteristics of 4 weeks old plants grown under conventional tillage and reduced tillage with compost application

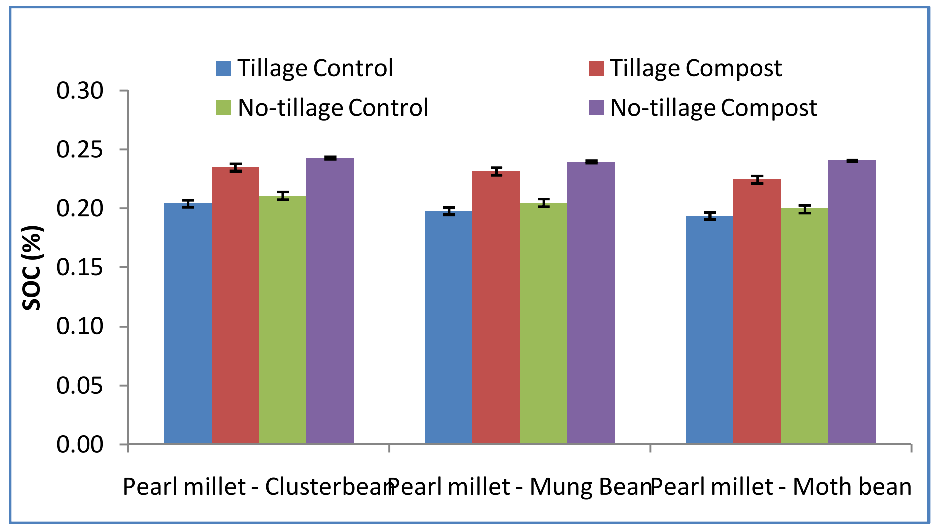
Crop/Root Characteristics	Root area (mm^2)	Average diameter of root (mm)	Root length (mm)	Number of root tips	Number of root nodules
Moth bean (*Vigna aconitifolia*)					
*Conventional Tillage	1368	0.526	4194	659	11
*Reduced tillage	1815	0.634	8079	1150	10
Cluster bean (*Cyamopsis tetragonoloba*)					
Conventional Tillage	2504	1.143	3614	492	2.0
Reduced tillage	2946	1.305	3830	442	5.0
Mung bean (*Vigna radiata*)					
Conventional Tillage	4564	0.901	7073	767	8.0
Reduced tillage	5091	1.034	8532	1000	16

* Conventional tillage and reduced tillage were practiced in the plots for 10 consecutive years

Tillage and Compost Effect on Yield and SOC in Arid Soils

- Significant soil carbon stock increase under no-till compared to full-till only in the upper soil (0–30 cm) of around 4.6 Mg/ha (0.78–8.43 Mg/ha) over 10 years.
- In contrast, tilled soils support a deeper rooting pattern in crops, leading to higher C input in the sub-surface layers, which also gets mixed throughout the soil due to tilling operations.
- Greater microbial biomass and soil enzyme activities observed under no-till compared to full tillage.
- Majority of the no-till systems show yield declines in the initial years because of the time taken for soils to stabilize following the transition from conventional tillage.





- One of the major problems in arid and semiarid regions is limited crop residue production with non-irrigated crops

Praveen-Kumar (2007); Zuber and Villamil (2016)

Tillage effect on performance, stability, SOC

- In arid region, **zero-tillage was found to be significantly inferior to conventional tillage** in pearl millet production system. Yield pf pearl millet were recorded higher under conventional tillage than no tillage in four consecutive years of field experiment (Aggarwal et al., 1998).

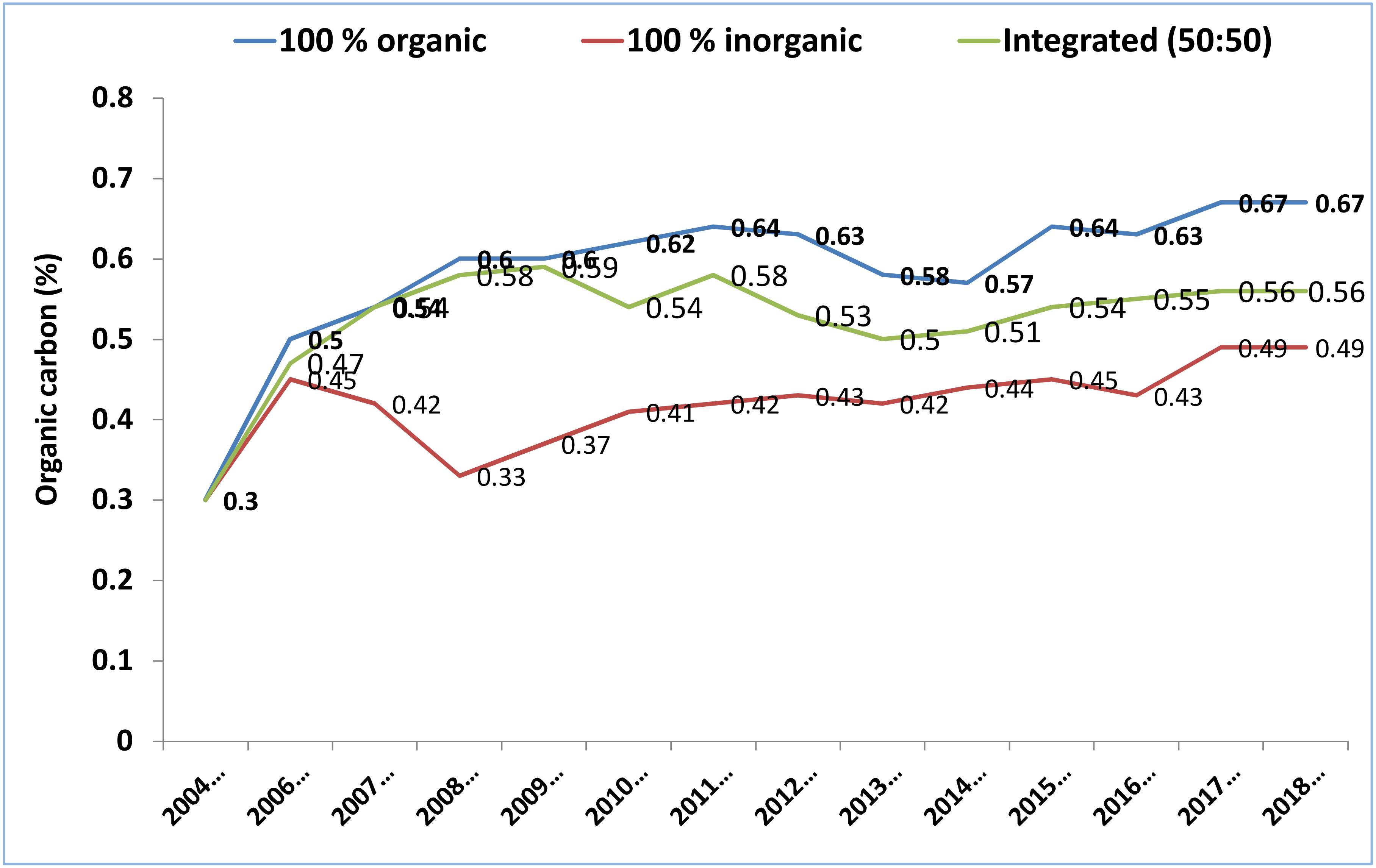
- Even after four years of cultivation, **pearl millet yield under reduced tillage remained lower than in tilled plot**. However, when reduced tillage is followed after legume crop rotation or after compost application, slight improvement in yield was observed under reduced tillage than tilled plot (Parveen Kumar et al. (2009).

- Long term field experiment in sorghum-mung bean crop rotation with different integrated nutrient management (INM) treatments revealed that **yield of sorghum remained consistently lower under reduced tillage than conventional tillage up to 8 years**. It showed that positive effect of reduced tillage on grain yield was possible after a long period of practicing it (Sharma et al., 2005)

- Long term field experiment in arid zone revealed that **average pearl millet yield was higher under reduced tillage as compared** to conventional tillage in different cropping system after practicing of reduce tillage system for 10 years

- In contrary, **deep ploughing in arid zone showed higher yield** (5-15%) over conventional ploughing from the field experiments carried out at Bikaner

Trend of organic carbon content in soil under various production systems (AI-NPOF, Ludhiana)



Adoption of IFS

- >50 IFS models in country
- >75% area under IFS (Silvi-pasture, Horti-pasture, Agri-horti, Agroforestry:
  - In majority of cases >3 components
  - Traditional crop-livestock farming system
  - New innovations are occurring
- New crops and commodities are being added

Farming System Components	% Farm House
Arable Crops	100
Agro-forestry	100
Livestock	97.6
Fruit plants	53.3
Vegetables	14.5
Fodder	12.1

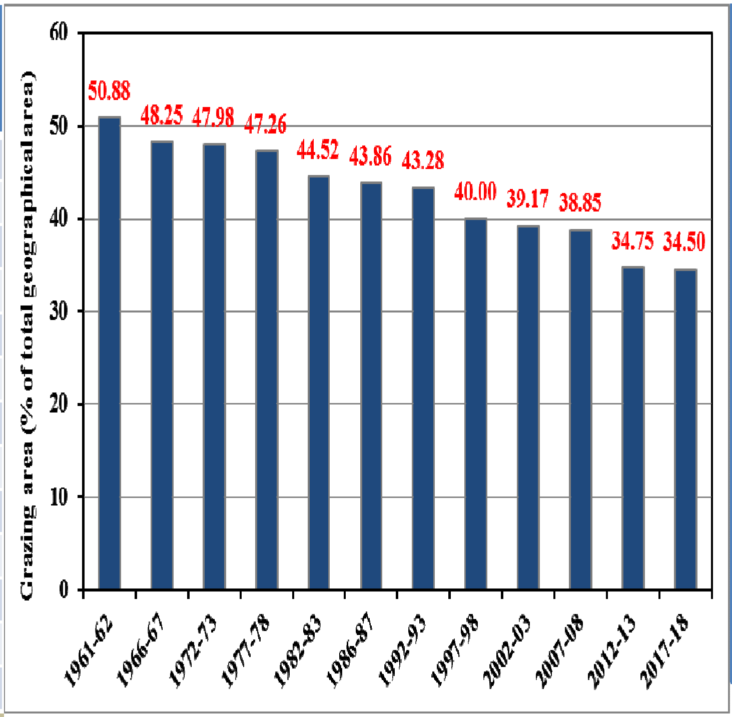
1. Diversification and innovations in IFS

- Large ruminants for higher income
- Horticulture and protected cultivation for resilience, higher water productivity
- New crops (e.g. seed spices in arid regions) and innovations
    - Greater resilience
    - Higher income
    - Risk aversion
    - Improved livelihood

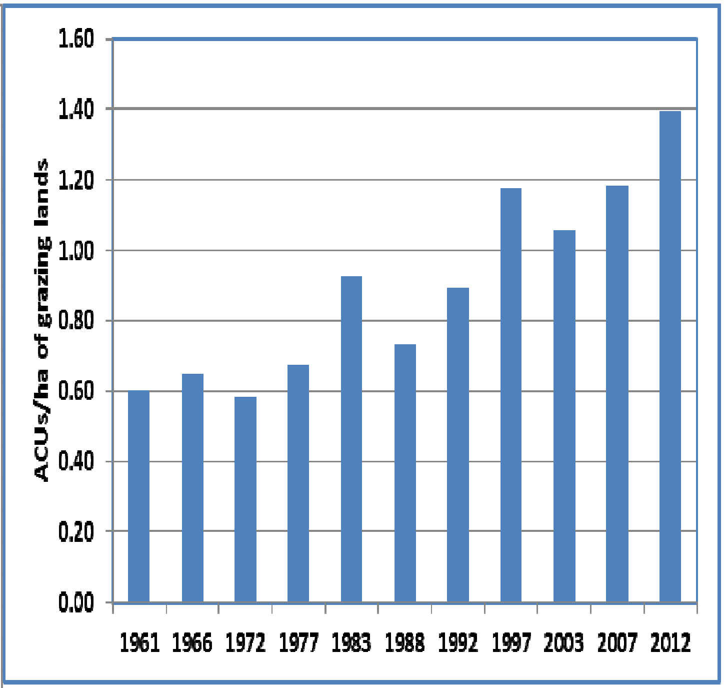
2. Experience of regenerating grasslands – Western Rajasthan

Year	Livestock (million)	Density of livestock (per 100 ha)
1951	10.34	49.7
1956	13.40	64.4
1961	13.72	65.9
1966	16.21	77.9
1972	16.28	78.2
1977	19.13	91.9
1983	23.13	112.1
1988	17.77	85.4
1995	26.22	129.0
2001	29.25	140.6
2007	29.11	140.2
2012	30.18	140.5
2019	27.85*	135.1

Livestock Population (millions) and density per 100 ha in arid Rajasthan



Trend in grazing area (CPRs) in western Rajasthan



Grazing pressure (ACU/ha) on the grazing resources of arid Rajasthan

Sources: Land use statistics, Government of Rajasthan); Tewari and Arya, 2005; Livestock Census, 2019

- Loss of desirable and palatable fodder species from the grazing lands.
- Adverse effect on regeneration of native plant species and seed production.
- Substantial decrease in the carrying capacity of grazing lands
- Reduction of species richness
- Loss of fertile soil and increased soil erosion.
- Increased desertification

2. Experience of regenerating grasslands – Kutch Banni grasslands

Technological intervention for increasing fodder production from pasture lands

1. Protection from grazing
2. Soil and water conservation
3. Reseeding of suitable grass species
4. Manure and fertilisers
5. Intercultural operations and fodder utilisation
6. Introduction of new fodder crops

Conclusion

- IFS has a key role to play in RA
- Dynamism is consistent in IFS
- Ecosystem services – to be recognized/ rewarded/ awarded
- Adequate policy to be in place with proper implementation

Thanks