Management of Natural Resources for Sustainable Dryland Agriculture

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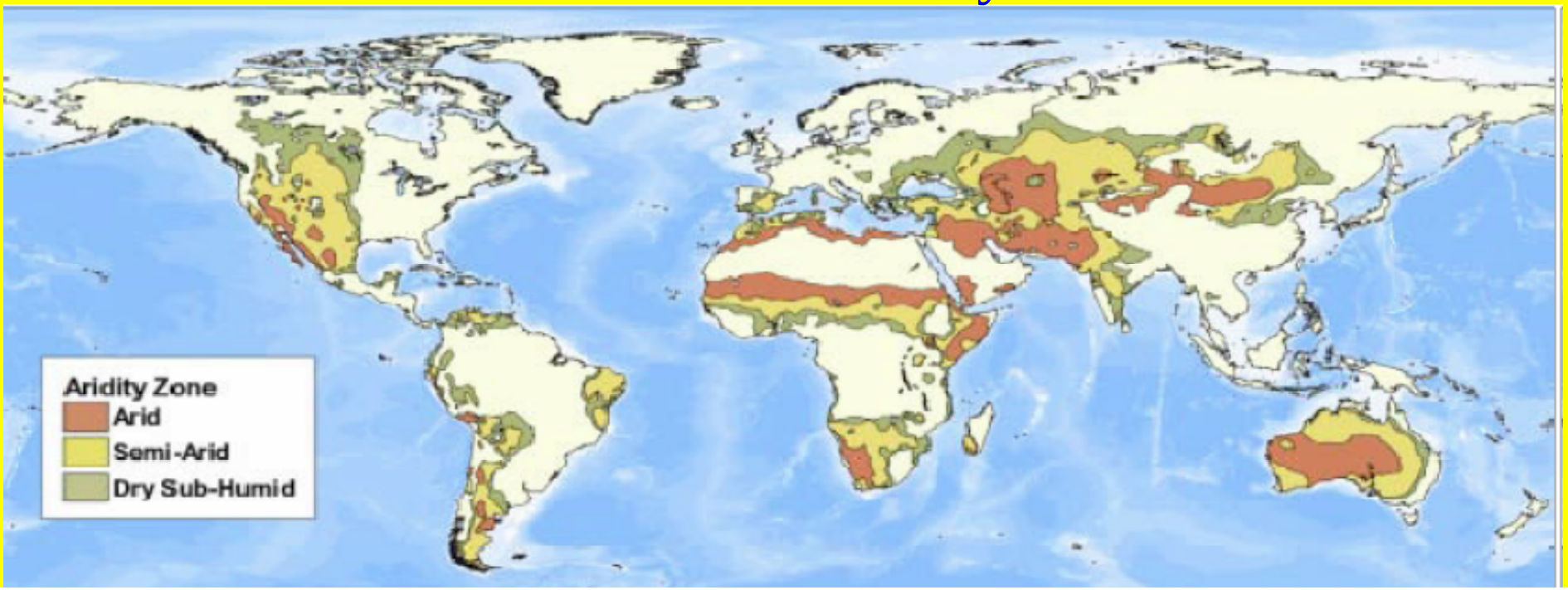
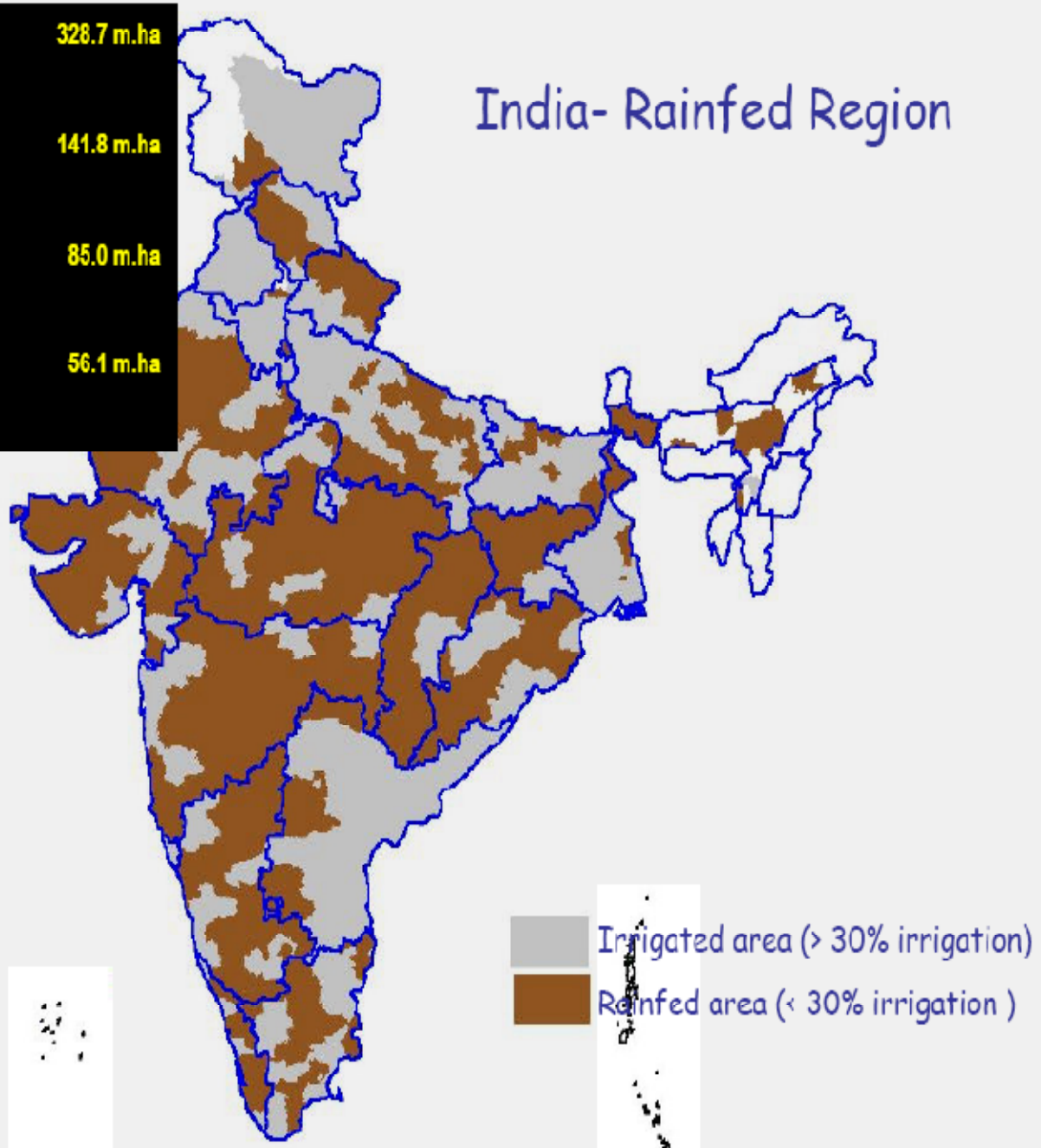
Extent of world's dryland



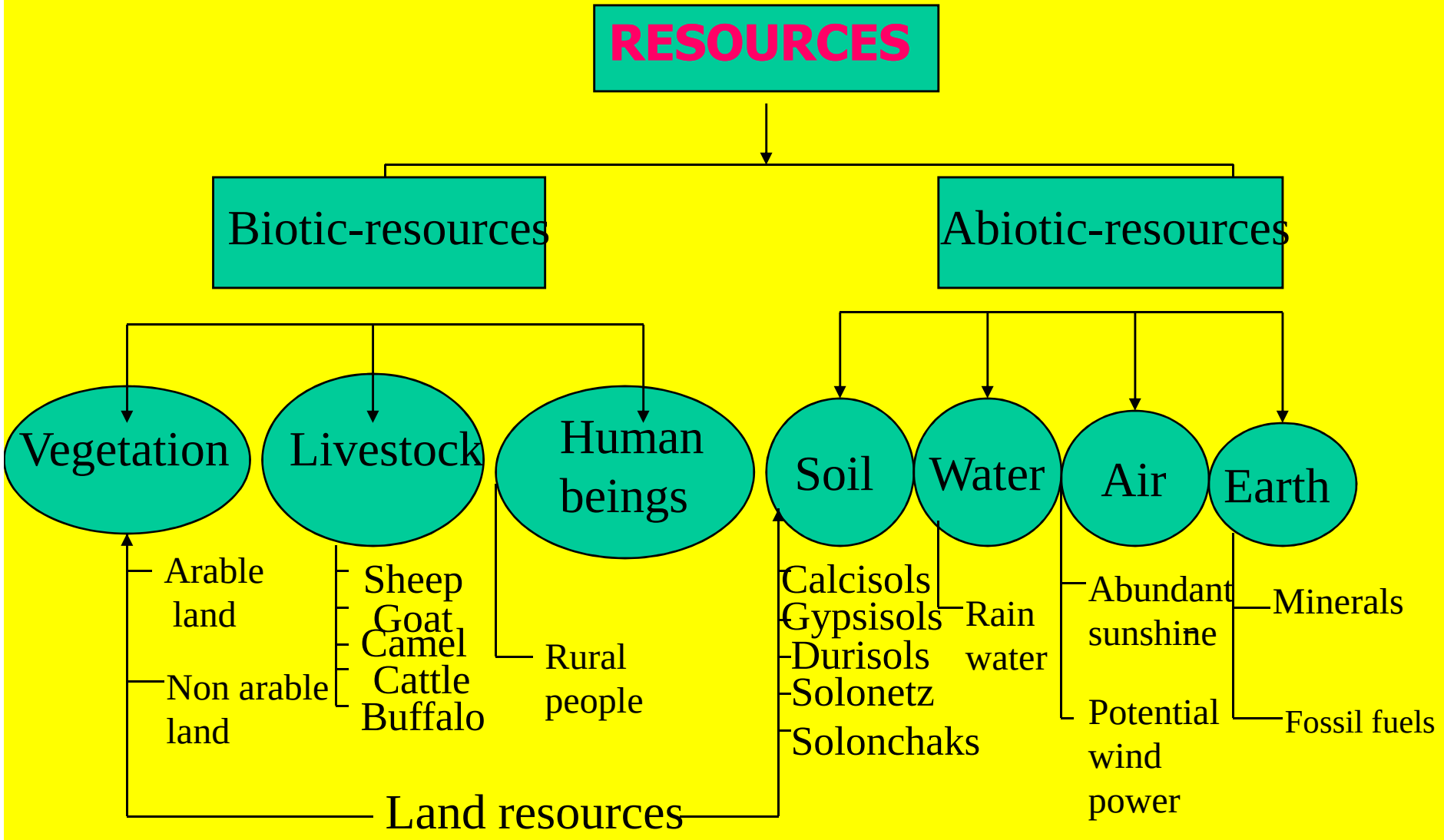
	Aridity Zone							
Region	Arid	%	Semi-Arid	%	Dry Sub-Humid	%	All Drylands	%
Asia (Incl. Russia)	6,164	13	7,649	16	4,588	9	18,401	39
Africa	5,052	17	5,073	17	2,808	9	12,933	43
Oceania	3,488	39	3,532	39	996	11	8,016	89
North America	379	2	3,436	16	2,081	10	5,896	28
South America	401	2	2,980	17	2,233	13	5,614	32
C. America & Caribbean	421	18	696	30	242	10	1,359	58
Europe	5	0	373	7	961	17	1,339	24
World Total	15,910	12	23,739	18	13,909	10	53,558	40

Source: UNSO/UNDP 1997.

Geographical area	328.7 m.ha
Net cultivated area	141.8 m.ha
Net Rainfed area	85.0 m.ha
Net Irrigated area	56.1 m.ha



Natural Resources in Dryland

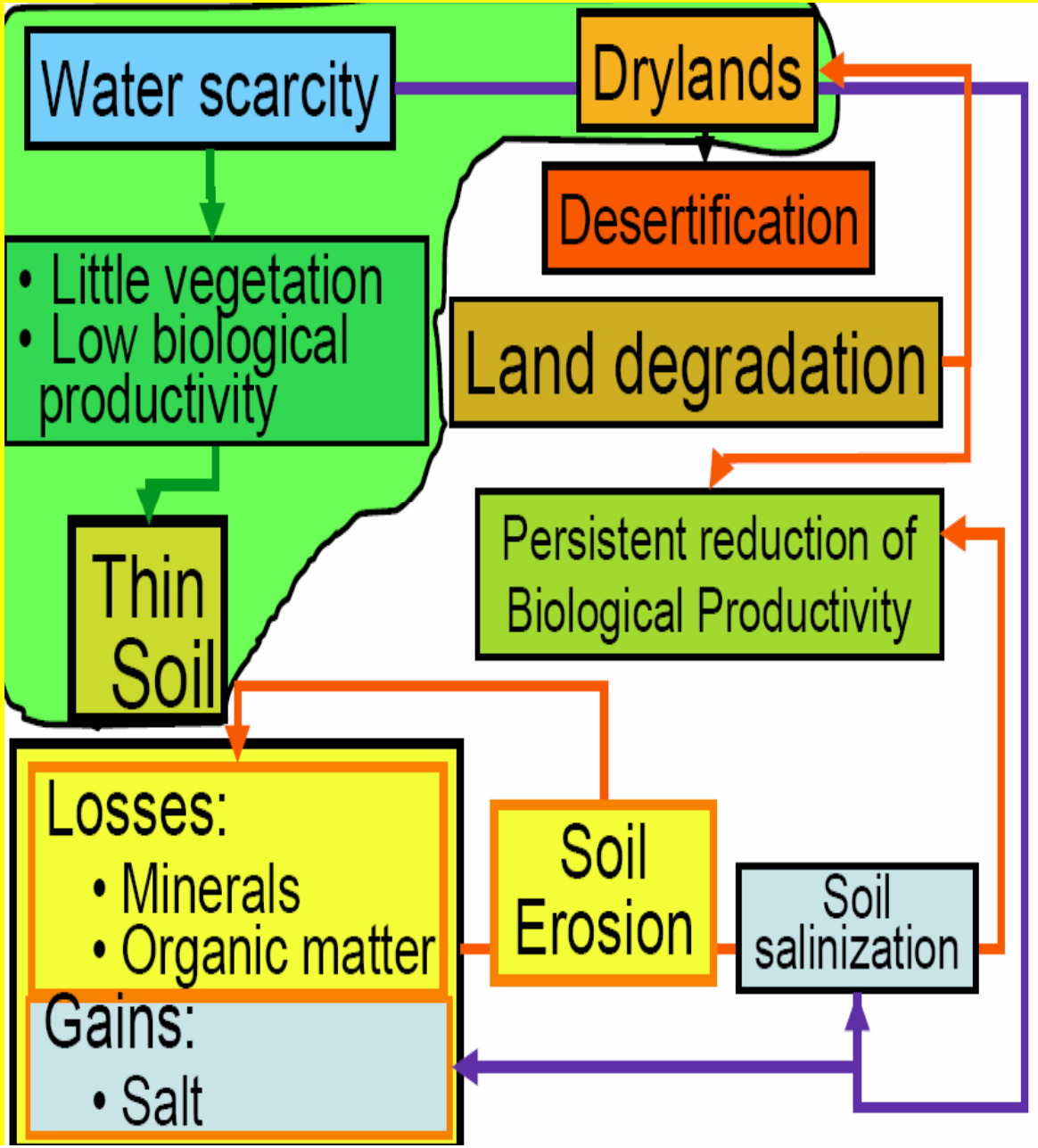


Characteristics of Dryland

- **Annual evaporation exceeds rainfall**
- **Agricultural productivity is limited by poor availability of moisture**
  - **» Semi-arid areas (200 – 500 mm rain)**
  - **» Arid areas (200 – 25 mm rain)**
  - **» Hyper-arid areas (less than 25 mm rain)**
- **Fragile environment with sparse vegetative cover**
- **Most of the area is already naturally degraded to different extents**
- **Limited arable land resources**
- **Recurrent droughts**

Challenges in dryland

- **Challenges in dryland are complex**
- Rising population implies increasing food demands
- Intensification of farming and poor farming practices- Nutrient mining
- Overgrazing and excessive tillage leave exposed soils
- Soil erosion leading to crusted soil and increased water loss due to runoff
- Loss of biodiversity



Management strategy of natural resources

1. Comprehensive field survey of natural resources.
2. Conservation and efficient use of natural resources
3. Economically feasible and environmental appropriate technology (farm ponds, sprinkler, drip & landshaping)
4. Conjunctive use of surface and ground level resources.(Imnr)
5. Optimum use of scarce natural resources (scientific)
6. Fixing priority in soil and water use (capability)
7. Reuse of water and alternate use of land (house, sewage)
8. Rainwater harvesting for replenishing ground water and renovation of the traditional source of storage of rain water
9. Priority for completion of on going projects

Sustainable water management

Average summer/winter rainfall (mm) at some dryland research centre

Station	Rainfall		Station	Rainfall	
	Summer	Winter		Summer	Winter
Agra	590	62	Jodhpur	310	37
Anantpur	320	**202**	Ludhiana	530	75
Bellary	**291**	185	New Delhi	465	60
Bhilwara	**600**	**50**	Rajkot	590	30
Bijapur	405	217	Sardarkrishi Nagar	530	60
Hisar	320	45	Solapur	535	150

Oswal, 1994

1. *In-situ* conservation practices

1.1 Off season land treatment

- reduces weed growth and retains more moisture

Summer tillage for alluvial, red and other light soils

Compartment bund for heavy black soils for assured rabi crops

1.3 Conservation furrow

-retains about 37% additional soil moisture compared to farmers' practice
-better plant growth and higher yields by about 17%

1.2 Cultivation across slope
- helps in retaining 10% more rainwater

Castor + Pigeonpea

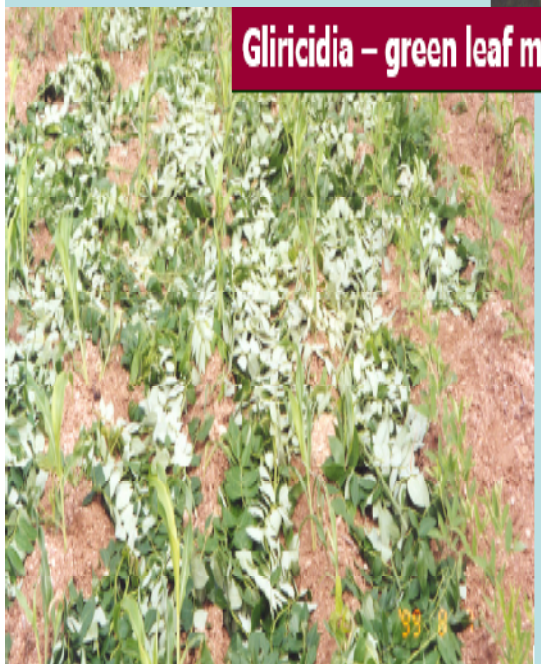
Groundnut

1.4 Mulch-cum-manure technique

Sunhemp – green **manure** for black soil

- reduces runoff (about 40%)
- reduces evaporation
- increases infiltration
- supplements nutrients (N, P, OC etc.)

Gliricidia – green leaf manure in sorghum and castor



1.5 Ridges and furrows system in cotton

-additional yield of 500 kg/ha over farmers' practice

1.6 Micro-catchments for establishment of Jatropha

Influence of soil and water conservation measures on crops at different locations

Crop (No of Years)	Location	Soil	Treatment	Yield (kg/ha)	SI
Pearl millet (3)	Agra Arid	Inceptisols	**Nutritious cereals** I. Raised bunds (20 cm high) with rectangular belts (6 X 2.7 m) across slope II. Compartment bunding (3 X 4.5 m) Farmers' method (control)	 2193 2153 1845	 0.67 0.66 0.46
Peal millet (3)	Dantiwala Semi arid	Aridisols	I. Compartment bunding (3 X 4.5 m) II. Flat sowing and ridges at 3 m distance Farmers' method (control)	1132 986 819	0.67 0.57 0.46
Caster (3)	Dantiwala Semiarid	Aridisols	**Oilseeds** I. Ridges and furrows II. Flat bed Trench (control)	 1668 1598 1412	 0.40 0.38 0.30
Vegetables (3)	Agra Arid	Inceptisols	**Horticulture** I. Ridges and furrows Flat sowing (control)	 6652 5008	 0.77 0.55
Gooseberry (4)	Rajkot Semi arid	Vertisols	**Agroforestry** I. Soil mulch II. Straw mulch Farmer's method (no mulch) (control)	 5 m height 53 cm dia 5 m height 48 cm dia 5 m height 48 cm dia	 0.92 0.92 0.90 0.83 0.92 0.79

1. I and II are the top first and second rated treatments
2. Height and diameter of tree was measured in the absence of yield

Vittal, *et al.*, (2002)

Water harvesting and reuse offers sustainability

Indigenous rainwater harvesting technologies in semi-arid regions of India (ICAR, 1999)

System	Technology	Region
Kunta	Small size community pond for providing suppmental irrigation to paddy, chillies and tobacco during long breaks in rainfall	Prakasam, Guntur and Nizamabad (Andra Pradesh)
Percolation tank	Used for recharging the groundwater to bring stability to rainfed agriculture	Andra Pradesh, Karnataka and Maharashtra
Haveli	Storing rainwater by raising field bunds used in Kharif fallow	Madhya Pradesh Mahakaushal Area
Risers	Stone pitching of bench terrace risers to conserve rainwater	Hilly regions
Stone pitched barriers	Stone pitching along with stubbles of pigeonpea/sorghum/cotton across the slope for rainwater conservation	Vidarbha region of Maharashtra
	Field bunds with waste weirs, stone checks and stone/boulder boundaries to conserve rainwater	Andhra Pradesh, Gujarat and Karnataka

Dohare and Singh, 2003

Estimated potential volume of rainwater storage for small-scale water harvesting structures (Katyal, 1997)

Rainfall zone (mm)	Geographical area (million ha)	Rainwater availability (million ha)	Harvestable runoff (million ha m)
<500	52.07	15.6	0.78
500-750	**40.26**	**25.2**	**1.51**
750-1000	65.86	57.6	4.03
1000-2500	137.24	205.9	14.61
>2500	32.57	95.7	3.26
Total	**328.0**	**400.0**	**24.19**

Dohare and Singh, 2003

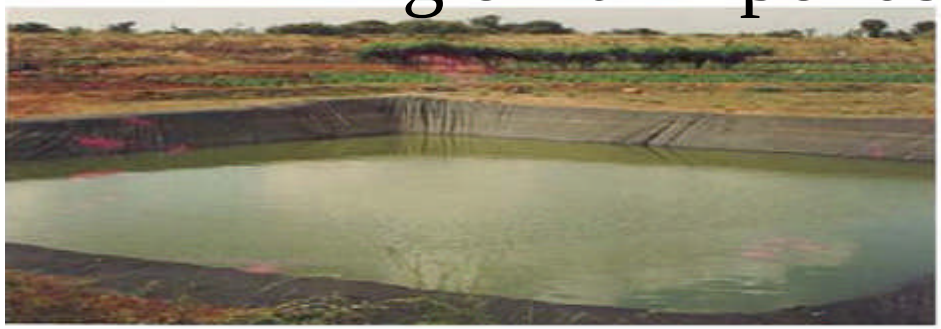
Improved Tanka in a village, Rajasthan.

Runoff harvesting in tanka for drinking and Silvi-pasture development at Kalyanpur

Common farm pond as a shard Asset among four farmers families

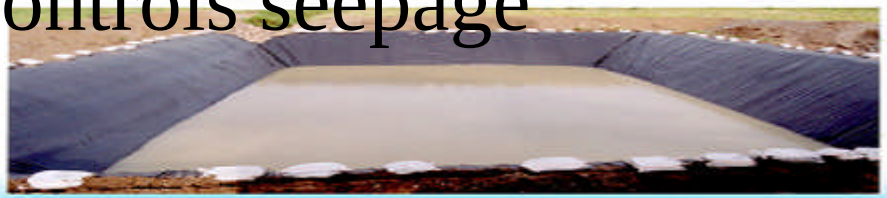
Percolation tanks

Lining of farm ponds controls seepage



A farm pond lined with cotainment liner to control seepage

(life of containment liner life is 4 years)



Capacity of pond	500 m 3
Evaporation	95 m 3
Seepage	nil
Available water for irrigation	405 m 3
Water required for irrigation (50 % CPE)	349 mm
Command area	0.12 ha

for growing vegetables in post rainy season

Some effective sealants for lining of farm ponds

Location	Sealant	Seepage as % of control
Dantiwada, Hyderabad	Plastic lining overland by cement plastering	0
Hyderabad	Red soil + black soil (1:2) compacted	10
Ludhiana	Bottom polythene lining	5
Varanasi	Soil + cow dung + Straw (7:2:1)	11
Rajkot	Black soil + Na_2Co_3 (2:1)	67
Hyderabad	Black soil + Na_2Co_3 (2:1)	4

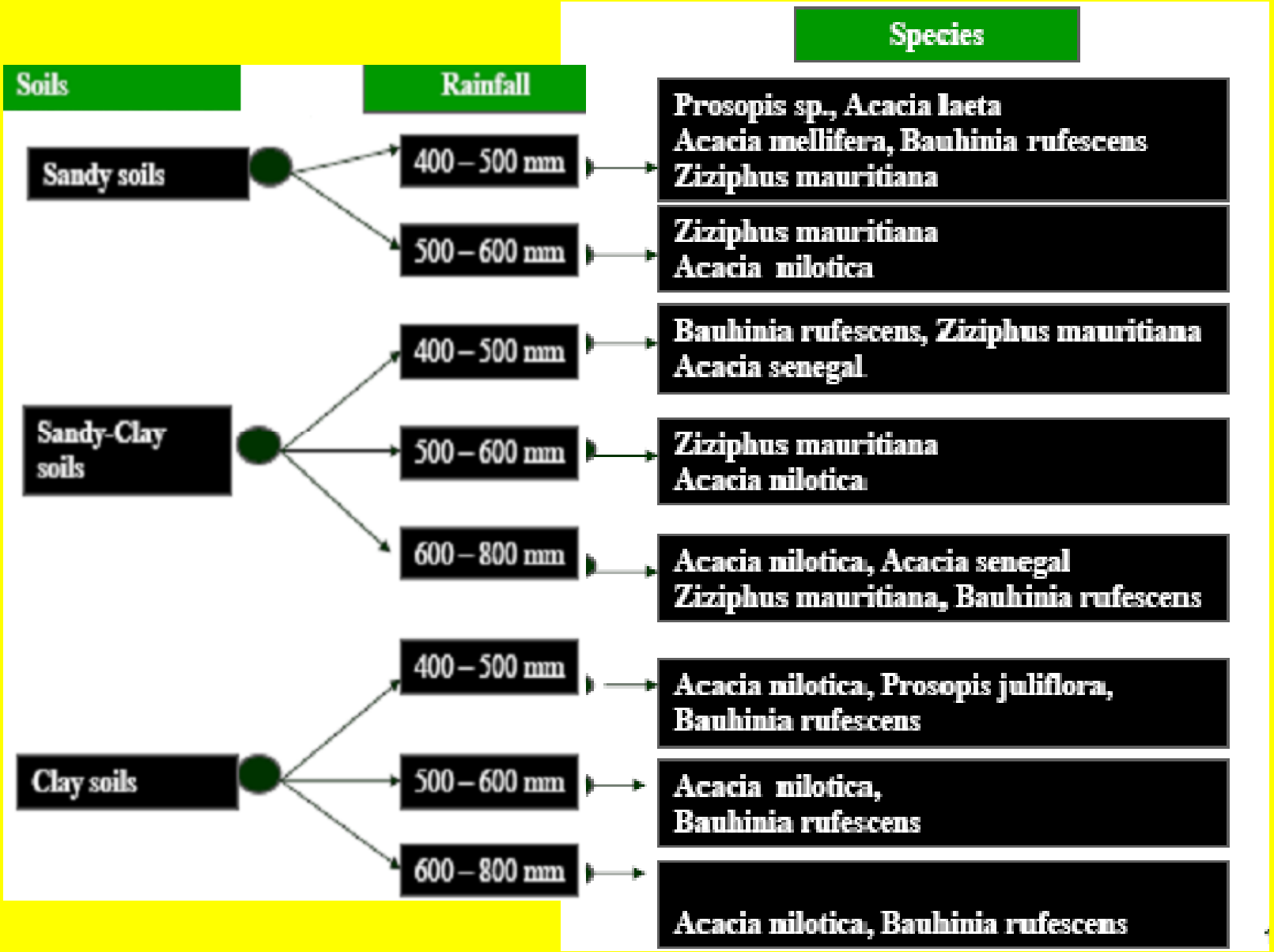
Oswal, 1994

Gully Plugs, Nagzari Village, (Oct. 1999). Photo: WOTR

Sustainable soil management

- **Regeneration of degraded lands and retention of soil moisture enhances agricultural productivity**
- **Planting trees and shrubs have proven to be very efficient in reducing wind erosion and stabilizing sand dunes in dryland**
- **Improved fallow systems, introduction of leguminous cover crops and nitrogen fixing and phosphorous cycling trees and shrubs have restored soil fertility to degraded drylands**
- **Live fences control wind erosion and protects crops from roaming animals**

Live fence species



➢ Trees when intercropped with crops add nutrients and organic matter to the soil and also reduce weeds and soil surface evaporation

› Covering the soil surface with organic materials such as straw, grass, etc reduces soil and runoff losses considerably.

Indigenous technical knowledge

– field bunds are time tested means of soil and water conservation

Stone bund (Bhilwara)

Agave on boundary bund (Bangalore)

Effect of Application of straw mulch on crop yield

Location	Crop	Yield (t/ha)	
		Control	Straw mulch
Agara	Barley	2.25	**2.99**
Anand	Tobacco	1.15	**1.27**
	Groundnut	1.17	**1.27**
Hisar	Chickpea	0.24	**0.70**
	Mustard	0.87	**1.77**
	Pearl millet	3.36	**3.43**
	Green gram	1.20	**1.22**
Hosiarpur	Wheat	2.28	**3.51**

Oswal, 1994

Pigeonpea, mungbean and pigeonpea equivalent yield as influenced by various treatments

Treatment	Pigeon pea yield (t/ha)	Mungbean yield (t/ha)	Pigeon pea equivalent yield (t/ha)
Cropping system			
Pigeon pea sole	1.48	-	1.48
Pigeon pea paired row (30/70 cm) + 1 row of mungbean	1.47	0.26	1.72
SEm ±	NS	-	0.05
CD (P=0.05)	-	-	0.016
Moisture conservation practices			
Dust mulch	1.41	0.202	1.51
Dust mulch + FYM @ 5 t/ha	1.51	0.262	1.64
Dust mulch + FYM @ 5 t/ha + Kaolin (6%) spray	1.52	0.275	1.65
SEm ±	0.04	0.006	0.006
CD (P=0.05)	0.012	0.019	0.018
P & S levels			
Control	1.23	0.167	1.31
P_2O_5 @ 40 kg/ha	1.42	0.220	1.53
P_2O_5 @ 40 kg/ha + S @ 25 kg/ha	1.58	0.274	1.72
P_2O_5 @ 40 kg/ha + S @ 25 kg/ha + PSB	1.69	0.323	1.85
SEm ±	0.018	0.008	0.019
CD (P=0.05)	1.054	0.025	0.058

NS= Non significance,

Rana, 2005

Production of pearl millet as influenced by ley farming

Grass ley	Grain Yield (Kg/ha)			Stover yield (Kg/ha)		
	With stubble		No stubble	With stubble		No stubble
CCF[a] + no fertilizer		850			2200	
CCF + fertilizer		1015			2716	
4-year ley	**950**		892	**3090**		2833
6-year ley	**1292**		1050	**3920**		3350
8-year ley	**1450**		1227	**4467**		3910
Statistical significance						
Ley LSD		156			261	
Stubble LSD		117			180	
Ley X Stubble LSD		NS			NS	

[a]CDF= conventionally cultivated field

[b]p = 0.05; NS= Non-significant

Rao *et al*., 1997

Stabilization of sand dune using vegetative method.

Micro-wind breaks- *Leptadenia pyrotechnica* (Khimp), *Ziziphus nummularia* (Pala), *Crotalaria burhia*(Sania) and *Panicum turgidum* (Murath)

Rehabilitation of a mine spoil area through vegetative measures. (Mostly grasses)

Reclaimation of sodic soil

50% of soil gypsum requirement + quantity of gypsum needed to neutralize the RSC in excess of 10 me L^{-1}

Yield of clusterbean under different contour vegetative barriers

Contour	Seed yield (kg/ha)			
	1992	**1993**	**1994**	**Mean**
Cenchrus	543	390	**1283**	739
Barleria + Symbopogon	469	333	**1459**	754
Cenchrus + Symbopogon	1122	375	**989**	829
Ubhorbia	408	626	**1252**	762
Control	496	378	**772**	549

Sharma *et al.*, 1997

Effect of deep ploughing on yield (t/ha) of some dryland crops

Tillage & its depth	Pearl millet (New Delhi)	Maize (Ludhiana)	Wheat (Ludhiana)	Tobacco (Anand)	Sorghum (Solapur)
Country ploughing (8-10 cm)	2.24	2.22	2.38	0.89	0.82
Deep ploughing (35-45 cm)	**2.56**	**2.65**	**2.81**	**1.04**	**0.93**

Oswal, 1994

Effect of wind erosion control measures on soil and water conservation, soil fertility, growth and yield of dewbean and culsterbean on marginal lands eroded by wind (Shekhawati area,aridisols)

Wind erosion control measures	Plant height (cm)	Grain yield (kg/ha)	Soil loss/ conservation (cm)	OC (%)	Soil moisture at harvest (%)
Dewbean (2000)					
Ridge & Furrow	27.0	310	-0.82	0.38	1.98
KBTS*	**31.2**	**410**	**-7.55**	**0.43**	**2.92**
KBPR**	28.1	360	-5.38	1.23	2.66
Control	21.0	245	-5.6	0.13	1.23
CD (P=0.05)	3.8	45	-	0.66	-
Culsterbean (2001)					
Ridge & Furrow	101.8	285	-0.92	0.40	2.36
KBTS*	**111.9**	**348.5**	**-6.52**	**0.44**	**3.24**
KBPR**	105.4	275	-5.75	0.26	2.73
Control	77.3	208.5	-6.34	0.14	1.64
CD (P=0.05)	14.8	37.3	-	0.05	-

*KBTS-Kanabandh of tree sticks (compact structure)

**KBPR- Kanabandh of plant residues (lose structure)

Poonia and Singh, 2005

Alternate land use system

Acacia albida-based agri-silviculture for sustainable income from rainfed farming.

Pasture development on shallow sandy degraded lands

A ber-based horti-pastoral system for income from rainfed farming during drought.

Bio-diesel crop based Intercropping
eg. Jetropha-Pongamia

Performance of different tree species and crops for alternate land use at Arjia (semi arid vertisols)

System (no of years)	Treatment	Yield (kg/ha)	SI
Silvi-pasture(5)	Agroforestry		
	I. *Prosopis cineraria*		
	+ *Cenchrus setigerus*	3483	0.61
	II. *Jetropha* + *green gram*	63	0.57
Silvi-pasture(5)			
	I. *Cenchrus setigerus* (100%)	2670	0.58
	II. *Cenchrus setigerus* (50%)	1813	0.55
Silvi-pasture(3)	I. *Acacia tortilis* (bunding and chiseling)	1716	0.94
	II. *Parkinsonia aculeata*	1545	0.82

I and II are the top first and second rated treatments.

Vittal, *et al.,* (2002)

Crop management

Efficient cropping systems for different situations (Singh, 1995)

Soil and region	Water availability Period (days)	Double cropping system	Intercropping system
Vertisols and related soil zones			
Malvapleteau (M.P.)	210-230	Maize-safflower-chickpea	Maize + Soybean
	191-210	Sorghum-safflower/chickpea	Soybean + Pigeonpea
Bundelkhand (U.P.)	190-220	Sorghum-chickpea, Black gram-mustard/safflower	Pearl millet + fodder legume Sorghum + Pigeonpea
Vidharbha (Maharastra)	190-210	Groundnut-Safflower Sorghum-safflower	Sorghum + Pigeonpea Cotton + Pigeonpea
	170-190	Greengram-Sorghum/Safflower	Pearlmillet +Greengarm Sorghum + Greengarm
Southern Maharastra	160-180	Greengram-Sorghum/Safflower	Pearlmillet + Pigeonpea Sunflower + Pigeonpea Groundnut + Sunflower
Southern Rajasthan	160-180	Greengram-Safflower	Miaze + Pigeonpea Groundnut + Pigeonpea Chickpea + Mustard
Northen and central Karnataka	130-150	Cowpea-Sorghum Greengram-Safflower	Pearlmillet + Pigeonpea Groundut + Pigeonpea Sunflower + Pigeonpea
	100-120	-	Sorghum + Coriander Safflower + Coriander

Contd..

Saurastra (Gujarat)	130-140	-	Groundut + Pigeonpea Pearlmillet + Pigeonpea
Southern Tamil Nadu	120-130	-	Sorghum + Blackgarm Cotton + Blackgarm
Alfisols and related soil zones			
Southern Karnataka	190-220	Cowpea-Fingermillet Soybean-Fingermillet	Fingermillet + Pigeonpea Groundnut + Pigeonpea Fingermillet + Soybean
Telangana (Andra Pradesh)	140-160	-	Sorghum + Pigeonpea Castor + Clusterbean Groundnut + Pigeonpea
Rayalaseem (Andra Pradesh)	110-130	-	Groundnut + Pigeonpea Groundnut + Pearlmillet
Arid soil zone			
North western Gujarat	100-120	-	Pearlmillet + Greengarm Pearlmillet + Clusterbean Clusterbean + Greengarm
	75-90	-	Pearlmillet + Blackgarm Pearlmillet + Clusterbean Clusterbean + Blackgram Pigeonpea + Blackgram

Land use efficiency, sustainable yield index and soil organic carbon content of different cropping systems (mean of four years)

System	LUE (%)	SYI	SOC (%)
Mono-cropping systems			
PM-Fallow-Fallow-Fallow	13.7	-	0.140
PM-Fallow-PM-Fallow	24.7	0.09	0.153
PM-Fallow-CB-Fallow	24.7	0.30	0.167
PM-Fallow-GG-Fallow	21.2	0.22	0.165
PM + Senna	-	**0.81**	0.143
Double cropping systems			
PM-Mustard- PM-Mustard	**57.5**	0.35	**0.183**
PM-Isabgol- PM-Isabgol	56.2	0.41	0.152

SOC= Soil Organic Carbon;
LUE= Land Use Efficiency

Saxena *et al.*, 2005

Relative profitability (Rs.) of different systems (pooled for 2 years)

Treatments	Total variable cost	Gross returns	Net returns
Sole Pearl Millet	1694	6555	4861
Mixed cropping			
Pm + C (25:75)	1448	2115	667
Pm + C (50:50)	1513	2918	1405
Pm + C (75:25)	1529	3501	1972
Row intercropping			
Pm + C (1:1)	1668	7512	5844
Pm + C (2:1)	1517	3817	2300
Pm(pr) + C	1548	3746	2162
Pm(tr) + C	1584	3426	1842
Strip cropping			
Pm + C (4:4)	1578	5009	3431

Pm= Pearl millet, C= Clusterbean,
Pr= Paired row, tr= Triple row

Singh and Joshi, 1994

Integrated nutrient management of crops under permanent manure trial

Crop (No. of years)	Location	Soil	Treatment	Yield (Kg/ha)	SI
Pearl millet (5)	Agra (Arid)	Incept-isols	I. 50% N urea + 50% FYM II.RDF + $ZnSO_4$ @25kg/ha Control	2255 2210 1136	**0.73** 0.72 0.32
Pearl millet (5)	Kovil patti (Semi-arid)	Incept-isols	I. 100% N urea + 20 P + $ZnSO_4$ @25kg/ha II.50% N FYM + 50% N urea + 10 P Control	1234 1173 714	**0.13** 0.10 -0.09
Maize (5)	Rakh Dhiansar (Sub humid)	Incept-isols	I. 100% RDF, NPK + $ZnSO_4$ @20kg/ha II. 100% RDF, NPK (60-40-20) Control	3633 3511 1544	**0.76** 0.74 0.31
Sorghum-Safflower (3)	Bijapur Semi-arid	Verti-sols	I. RDF + $ZnSO_4$ @15kg/ha II.50% N, FYM + 50% RDF Control	954 871 245	**0.39** 0.33 -0.13

I and II are the top first and second rated treatments

Vittal *et al.*,2002

Effect of critical irrigation on performance of dryland crops

Location	Crop	Yield (t/ha)	
		Without at critical irrigation	With critical irrigation
Agra	Wheat	2.19	**2.74 (5 cm)**
Anand	Tobacco	1.21	**1.81**
Bellary	Safflower	0.13	**0.29**
Hisar	Pearl Millet	1.32	**2.24 (7 cm)**
	Mung bean	0.83	**1.30**
	Chickpea	0.58	**1.90**
	Mustard	0.75	**1.44 (5 cm)**
Hyderabad	Chickpea	0.82	**3.57**
Ludhiana	Sorghum	2.57	**3.57**
	Wheat	1.92	**4.1 (7 cm)**
Solapur	Chickpea	0.80	**1.04 (5 cm)**
	Safflower	0.77	**1.03**

Oswal, 1994

Effect of time of weed removal on nutrient uptake (kg/ha) by pearl millet at harvest and seed yield (sandy loam, Hisar)

Treatment	Nutrient uptake (kg/ha)				Grain yield (t/ha)	Stover yield (t/ha)
	Grain		Stover			
	N	P	N	P		
Unweeded	24.6	4.78	31.1	1.64	1.45	4.14
Clean weeded	**52.2**	**11.84**	**53.5**	**3.50**	**2.82**	**6.00**
Weed removal						
10 DAS	32.3	6.80	36.7	2.30	1.89	4.74
20 DAS	**42.8**	**9.44**	**44.4**	**2.90**	**2.42**	**5.37**
30 DAS	38.4	8.18	41.3	2.66	2.21	5.24
40 DAS	33.8	6.90	36.7	2.22	1.98	4.90
50 DAS	27.2	5.44	34.9	1.97	1.60	4.41
60 DAS	26.5	5.15	31.7	1.68	1.56	4.21
CD (5%)	3.2	0.76	4.4	0.30	0.12	0.33

Singh and Yadav, 1994

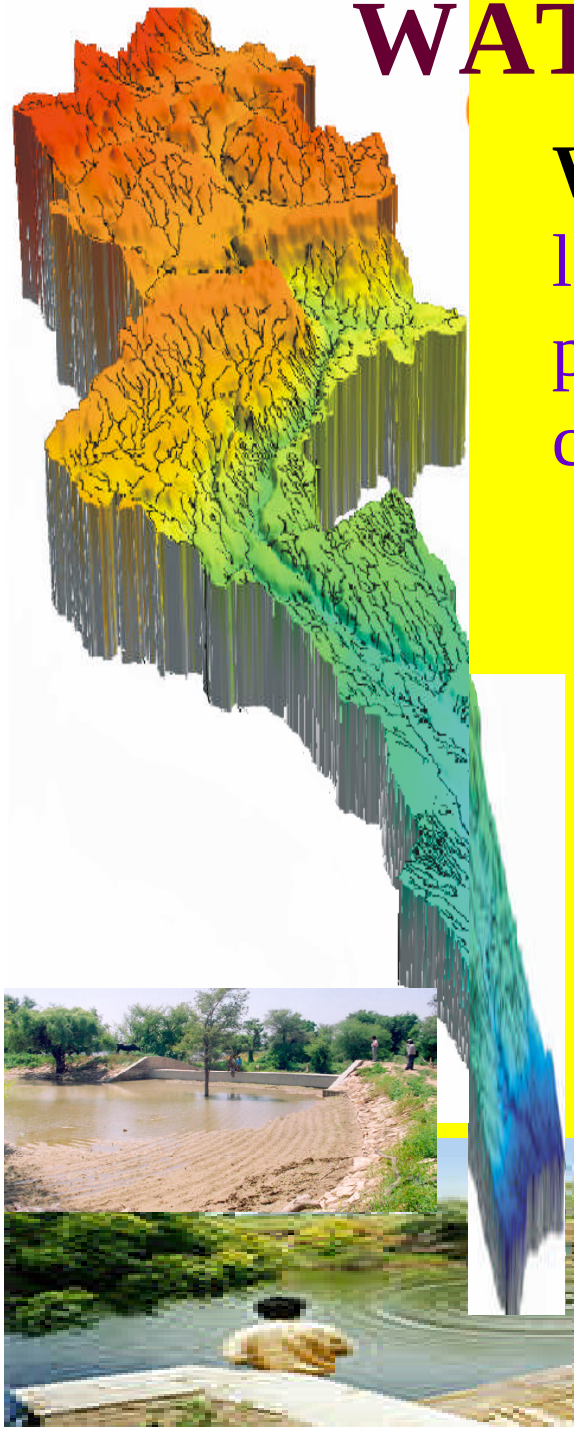
Sorghum grain yield as influenced by organic materials and synthetic amendments (2000-2006)

Treatment	Year 2005-06			6 years mean (2000-01 to 2005-06)		
	Sorghum yield (kg/ha)	Runoff (mm)	Soil loss (kg/ha)	Sorghum yield (kg/ha)	Runoff (mm)	Soil loss (kg/ha)
T_1-In situ green manuring through legume crop*	1663	38.1	1695	1062	29.1	1193
T_2-Application of subabul lopping @ 5 t/ha	2114	20.4	1184	1389	14.4	794
T_3-Incorporation of sorghum crop residue @ 5 t/ha	1989	29.8	1344	1253	20.8	998
T_4-Application of chemical amendment gypsum @ 5 t/ha	2079	39.7	1848	1196	31.3	148
T_5-Application of glyricida leaves @ 5 t/ha	2094	26.5	1304	1322	20.2	980
T_6-Control	1343	45.7	1946	886	37.3	1585
S.Em.±	35.24					
C.D.@5%	111.05					

*Sorghum + cowpea, incorporating cowpea after 45 DAS.

Nalatwadmath and Patil, 2005

WATER SHED MANAGEMENT



Water shed is a geo-hydrological area on land surface from which runoff from precipitation reach a particular point called common outlet.

MAIN COMPONENTS

- » Soil and water conservation
- » Water harvesting
- » Crop management
- » Alternate land use system

Watershed Management- A Holistic Approach

- The sum of collective efforts is greater than the parts.
- Working at the watershed scale opens up opportunities to plan and implement different strategies that complement and increase the benefits of in-field practices.
- The efforts are effectively targeted and coordinated.
- The most compelling advantage of working at the watershed scale is the ability to “focus for effect” to direct conservation efforts at the most vulnerable parts of the landscape and during the most vulnerable times of the year

Impact of interventions of surface runoff and soil loss in the watersheds

Watersheds	Surface runoff (%)		Soil loss (t /ha/yr)	
	Pre-project	Post-project	Pre-project	Post-project
Bazar-Ganiyar (Haryana)	7.3	**3.5**	NA	8.5
Behdala (H.P.)	30	**10**	12	**7**
Bunga (Haryana)	30	**21.6**	768	**435**
Chhajawa (Rajasthan)	50	**18.5**	NA	10.6
GR Halli (Karnataka)	1.4	**1**	1.4	**1**
Joladarasi (Karnataka)	NA	6.7	12	**2.3**
Siha (Haryana)	NA	1.5	NA	9.7
Aganpur-Bhagwashi (Punjab)	48.5	**24**	12.6	**2.8**
Antisar (Gujrat)	33	**16**	0.405	**0.042**
Badakhera (Rajasthan)	30	**10**	40	**10**
Bajni (M.P.)	25.4	**16.3**	12.1	**8.3**
Kokeiguda (Orrisa)	36.8	**12.4**	38.2	**6.6**
Salaiyur (Tamil Nadu)	4.5 to 7.2	**1.3**	1.7 to 8.9	**0.5 to 1.6**

NA- Not available

Singh, 2006

Influence of soil and water conservation measures

Crop (No of Years)	Location	Soil	Treatment	Yield (kg/ha)	SI
Wheat (6)	Hoshiarpur Sub humid	Inceptisols	Cereals I. Across the slope II. Round about	 2190 1882	 0.49 0.39
Maize (4)	Arjia Semi arid	Vertisols	Nutritious cereals I. Compartment bunding II. Sowing across slope Farmers practice (control)	 1802 1581 1357	 0.69 0.59 0.49
Finger millet (8)	Bangalore Semi arid	Alfisols	I. Graded border strips II. Graded bunds Farmers practice (control)	2175 1991 1738	0.68 0.62 0.53
Finger millet (7)	Bangalore Semi arid	Alfisols	I. *Khus* livebund in between earthen bund at 1m vertical interval II. Nasehullu (*Pennisetum hohenackeri)* Bund alone (control)	1941 1816 1629	0.73 0.67 0.59
Rabi sorghum (6)	Solapur Semi arid	Vertisols	I. Ridges and furrows II.Compartment bunding Harrowing (control)	878 796 609	0.15 0.10 -
Groundnut (6)	Anantapur Arid	Alfisols	Oilseeds I. Contour cultivation + compartment bunding II. Contour cultivation + dead furrow at 3.6 m interval Farmers' practice (control)	 1370 1292 1206	 0.33 0.30 0.26
Groundnut (4)	Anantapur Arid	Alfisols	I. Deep ploughing Farmers' practice (control)	1259 883	0.06 -0.10
Soybean (3)	Indore Semi arid	Vertisols	I. Keyline sowing with multidirectional slope of 1.3% II. Farmers' practice (contro)	1617 1287	0.68 0.53

1. I and II are the top first and second rated treatments

Vittal, *et al.*, (2002)

Sustainable use of biodiversity

Grassland Improvement and Management

Grasses are ideally suited for the dryland ecosystem eg.*Cenchrus ciliaris* (Anjan), *Lasiurus sindicus* (Sewan), *Cenchrus setigerus* (Dhaman), *Dichanthium annulatum* and *Panicum antidotale* and *Sehima nervosum etc.*

Contour furrows, contour bunds and contour trenches have been found to increase the forage yield. Regeneration of *L. sindicus* was much better after contour furrows were created.

Dryland trees and management

Azadirachta indica, Eucalyptus camaldulensis, E. terminalis, Acacia albida, A. tortilis, A. bivenosa, A. ampliceps, A.eriopoda, Colophospermum mopane, Dichrostychus nutans, Prosopis spp. (Peruvian), *P. alba, P.chilensis, Hardwickia binata,* and *Pongamia pinnata* have shown promises in Indian dryland. Plus trees of *Prosopis cineraria, Tecomella undulata, Acacia albida, A. senegal, A.nilotica* subsp *cupressiformis* and *A. tortilis* subsp *raddiana* have been identified.

Plants of medicinal and industrial values

Balanites aegyptica,
Commiphora wightii,
Euphorbia antisyphilitica,
Haloxylon,
Cassia angustifolia, etc.,

A variety of *Aloe* vera, which is a good source of gel and has high aloin content, has been identified in Thar desert.

LIVESTOCK MANAGEMENT

Multi-nutrient feed block

- Using low-cost ingredients like animal-grade jaggary, urea, common salt, mineral mixture and wheat bran are the local prepared multi-nutrient feed blocks for animals.

Non-conventional silage

- Tumba (*Citrullus colocynthis*) seed cake, a by-product of oil industry that contains 16-22% protein, has been found to be a healthy non-conventional feed for heifer.
- *P. cineraria* leaves have been made more digestible by removing tannin from it through heating with 0.5 N aqueous solution of sodium bicarbonate.

Nutritive value of basal feed and tumba cake

	Ingredient	DM	CP	CF	EE	NFE	TDN
Mean Digestibility Coefficients	**Wheat straw**	**50.30**	**56.42**	**56.50**	**48.80**	**50.3**	**-**
	Tumba cake	**43.96**	**54.60**	**55.14**	**65.87**	**60.99**	**-**
Digestible Nutrients	**Wheat straw**	**-**	**0.87**	**22.60**	**0.21**	**22.96**	**46.93**
	Tumba cake	**-**	**10.35**	**30.22**	**4.15**	**5.62**	**55.50**

DM=dry matter, CP=crude protein, CF=crude fiber
EE=ether extract, NFE=nitrogen free extract
TDN=total digestible nutrient,

Sharma *et al.,* 1996

Application of tumba cake @ 1.tonne/ha

improved the productivity by 50% of green gram variety PDM 54 at farmers' field in Manai Village near Jodhpur under low rainfall situation (ICAR/DARE Annual Report, 2003-04)

Management of dryland mineral resources

- **Mineral resources like limestone, gypsum, sand stone, dolomite, calcite, silica sand, marble, etc. and**
- **Fossil fuels such as crude oil, oil shale, sand tar, coal and natural gas are other natural resources in dryland areas.**
- **Systematic and planned mining operations, suitable site selection for waste disposal, proper exploration and utilization of these resources may help in socio-economic development of these areas.**

Conclusion and general recommendation

- » Dryland regions are harsh environment and need concerted efforts to improve productivity based on regional specificities.
- » Incorporate refined traditional/indigenous knowledge of land and water management techniques for wider acceptability.
- » Management of water alone is impossible without proper land management and vice versa.
- » Complimentarity between crop-centered and natural resource-centered technologies cannot be ignored.
- » Agricultural diversification and linking arable farming with animal husbandry is necessary for good management of natural resources.
- » Implementation of watershed development programme as a holistic approach needs to be encouraged in all the regions.
- » Management of natural resources by both public and government becomes crucial. (Limitation is the mother of good management.)

"Respect for water reaps plenty"

Thank you