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Resource conservation in arid and semi-arid regions of Gujarat

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ABSTRACT

Resource conservation is the planned management of natural resources to optimise their utility, efficient usage in their original application, reuse, and recycling. The aim is to minimise the energy consumed and wastes generated in all stages from production through the life of the product right up to final disposal. An effective resource conservation system can minimize impact on the planet by using the earth's resources wisely. For this, natural resources must be managed more efficiently to lessen the environmental impact of the products, from raw materials to production to distribution and on through ultimate disposal. In a pre-dominantly agricultural system, the objective of improving the productivity, profitability and prosperity of the farmers and achieving agricultural development on an ecologically sustainable basis can be attained only when conservation, development and management of the land and water resources are assured.

Key words : Agriculture, Arid zones, Semi-arid zones, Resource conservation

Ever since independence, India's planners and policy makers have shown concern for efficient use of land, water and other natural resources for accelerated and sustainable development. However, notwithstanding these concerns, the problems of land degradation and groundwater depletion have assumed serious proportions in several areas which threaten not only the sustainability of agriculture, but also the overall livelihood system of the people.

Soil and water conservation

Land and water are the natural resources that are essential for the existence of life. They are under tremendous stress due to the ever increasing biotic pressure. Land degradation is mainly due to soil erosion caused by natural and man made causes viz., deforestation, overgrazing, reckless mining and general mis-management. Physical and biological deterioration of land with associated fertility depletion also occurs due to water logging, salinization, alkalinization, acidification etc. To help reduce the pace of degradation and accelerate the process of development and conservation of land, water and vegetation in an integrated manner the watershed approach has been considered the most appropriate in recent times.

In India, an estimated area of 146.82 m ha suffers from various kinds of land degradation owing to water and wind erosion and other complex problems like alkalinity/salinity, water logging and soil acidity. Droughts and floods are also a common feature in many parts of the country. Out of total land, 42.5% is suffering from different degrees of soil degradation and water erosion is the major contributing factor (GOI, 2006). The watershed management should concentrate on these areas where soil is lost through run off and the strategy should be to prevent soil erosion while at the same time conserving surface run off.

Various approaches have been advocated and experimented to halt the process of degradation of these resources. Watershed approach of late has been considered appropriate to help reduce the face of degradation and the process of development and conservation of land, water and vegetation in an integrated manner. As watersheds support the entire dryland agriculture/horticulture, the strength of the watershed development programmes will largely determine the growth in agriculture.

Soil conservation

Land being the major non-renewable natural resource is inelastic in nature. There is lot of pressure on the land due to the increasing population from the agricultural, industrial and housing sectors. On the other hand, the land is subjected to soil erosion and degradation due to flood, wind and faulty cultivation practices resulting in loss of top soil, and thereby all soil nutrients. This leads to poor yields, uneconomic returns, reservoir sedimentation, and reduction in storage capacity, ecological imbalance, environmental pollution, droughts and floods. Hence the conservation, development and management of the land resources which ensures the physical, chemical and biological health of soil profile are of prime importance. Also a *sine qua non* for water resources management, right from soil moisture conservation to flood control.

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Watershed development and management

Watershed development and management is an integration of technology within the natural boundary of a drainage area. Water conservation and rainwater harvesting is best accomplished when taken up on watershed level. The watershed being a hydrological unit, any intervention to store rainwater or moderate the runoff responds more favourably when the programme is organised on watershed basis.

The concept of 'integrated watershed development' is that the development and management of the resources in the watershed should be taken up to achieve higher production that can be sustained without causing any deterioration in the resource base or causing no ecological imbalances. The aim is to prevent watershed degradation that results from the interaction of physiographic features, eliminate unscientific land use by appropriate cropping pattern, soil erosion thereby improving and sustaining productivity of resources leading to higher income and living standard in the watershed area (Table 1).

Table 1. Socio-economic impact of watershed management project

Parameters	Year of survey 1983	1990	Increase (%)
Change of cropping pattern (ha)			
Wheat	83	117	41
Sesamum	9	82	811
Castor	0	9	
Irrigation resources:			
Area under irrigation (ha)	31	112	261
Number of wells	72	110	53
Water lifting device	10	15	50
Recharging of water (ha-m)			
(a). Winter	31.1	112	260
(b). Summer	4.6	45	878
Agricultural income (Rs. in lakhs)	22.83	46.81	105

Source: Mayani (1992)

The strategies available for sustainable water management are: (i) rainwater harvesting with construction of farm ponds and check dams for ground water recharge to stabilize drinking water and irrigation wells, (ii) scientific use of water in canal irrigated areas and reduction of water loss, (iii) rehabilitation of water bodies, (iv) introduction of water saving irrigation methods like drip and sprinkler irrigation on a large scale, and (v) construction of community wells to promote conjunctive use of surface and ground water.

Water conservation

Our ancient religious books and epics give a good insight into the water storage and conservation systems that prevailed in those days. Over the year rising populations, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate water. Water conservation has become the need of the day. The idea of groundwater recharging by harvesting rainwater is gaining importance in many cities.

Dry farming

Dry farming is characterized by low crop productivity and high variation in yields from year to year. In dry farming areas, though the total rainfall received is adequate for crop growth, its distribution determines the crop productivity. The dry spells, due to erratic rainfall distribution, especially at critical stages, affect the yield adversely. In rainfed areas, all the rainfall received is not available for the crops and a significant part is lost as run off. This opens the potential for collecting the run off, store it in a pond and use it for providing life saving irrigations.

The annual average rainfall of the country is 1,140 mm which in other words estimated as 400 m ha-m. Out of which 180 m ha-m is lost through flow into rivers and about 150 m ha-m enters the soil. The remaining 70 m ha-m is lost as evaporation. Out of 180 m ha m of runoff, 20 m ha m is utilized; the rest being lost.

Out of total net sown area (142 m ha) roughly 63% land, produces about 45% of cereals and covers roughly 90% area under oilseeds and pulses. Even after achievement of ultimate irrigation potential (113.5 m ha) > 50 m ha will remain as rainfed in 2025 (Abdul Kareem, 1999).

Gujarat has around 2.5 m ha under irrigation (26% of total cropped area). Of this, 80% is irrigated by wells, 18% by canals and 2% by other sources, mainly tanks. Thus in Gujarat 74% of the agriculture is dependent on the vagaries of weather as against 70% at national level. The problem becomes more acute as the rainfall is erratic with high coefficient of variation (CV%). All these lead to the fact that appropriate rainfed water management technology is very important for this state (Rana and Raman, 1999). Gujarat constitutes about 20% of arid and 9% of semi-arid areas of the country. Next to Rajasthan, this area is maximum in Gujarat. Saurashtra falls under arid to semi-arid (potential-evapotranspiration 1,873 mm) and rainfall is low (761 mm) and erratic with 55% CV (Malavia *et al.*, 1999).

Rainwater harvesting

Agriculture development is at crossroads today. Despite an agricultural revolution in the developing world over the course of a single generation that has produced enormous benefits for farmers, consumers and economies, a number of second generation challenges in agricultural transformation have emerged. Issues such as disparities in agricultural growth, problem of food insecurity and decreasing diversity, plateauing productivity in certain crops, growing ecological imbalance and unsustainable agricultural practices have come to fore. Ironically, a large proportion of the rural community continues to live in regions with poor quality soils and unpredictable rainfall, and remote from agricultural services and markets, deprived of the gains of agricultural revolution.

"Water harvesting" is defined as the process of collecting and concentrating runoff water from a runoff area into a run-on area, where the collected water is either directly applied to the cropping area and stored in the soil profile for immediate use by the crop, i.e. runoff farming, or stored in an on-farm water reservoir for future productive uses. The collected water can also be used for groundwater recharge and storage into the aquifer, i.e. recharge enhancement. Rainfall failure occurs once every 3 to 5 years and is usually below 50% of the average of the region. During periods of rainfall failure, the groundwater level lowers since fluctuations in the water-table levels depend on the rainfall when both surface and groundwater availability becomes critical. Drought begins to prevail and there is difficulty to cope up with the water demand during this period. Similarly, in some areas water shortage is observed just before the rainy season commences. These two situations can be managed, if suitable soil and moisture conservation measures are systematically implemented on a watershed basis.

Conservation of water in the agricultural sector is essential since water is necessary for the growth of plants. A depleting water-table and a rise in salinity due to overuse of chemical fertilizers and pesticides has made matters serious. Various methods of water-harvesting and recharging have been and are being applied all over the world to tackle the problem. In areas where rainfall is low and water is scarce, the local people have used simple techniques that are suited to their region and reduce the demand for water.

Groundwater recharge

Where conditions are favourable, it is better to recharge the groundwater than to create surface ponds for storage. This approach minimizes evaporative losses, and often improves water quality (Table 2). Recharge structures can be anything from a small pit simply dug into the soil, to a borewell converted for recharge. Recharge structures are useful in sloping landscapes where the water would not otherwise have time to sink into the ground before running off. The structures should be located in relatively low areas, so the water will naturally flow into them. Another good location is behind a check dam, so that the water is slowed and has time to infiltrate. Great care should be taken to keep silt and debris from entering the recharge structure; otherwise it will block the infiltration of the water. This can be done by creating smaller pits to allow the silt to settle before the water enters the true recharge structure. If a borewell is used for recharge, development of the well (forcing of air or water into the well under pressure) will help to loosen the surrounding soil and increase permeability. Where possible, open recharge structures should be covered or treated to reduce mosquito breeding (neem juice can be used, or mosquito eating fish).

Creating a farm pond or tank

In India's arid and semi-arid areas, the 'tank' system is traditionally the backbone of agricultural production. Tanks are constructed either by bunding or by excavating the ground and collecting rainwater.

The ideal farm pond should be dug into the ground in a naturally low lying area. Some of the soil that is removed can be used to construct an earthen bund around the pond, which should be planted with trees and grasses for stability. The shade and wind protection provided by the raised mound and vegetation will reduce evaporative losses. Greater depth of the pond and less surface area will also reduce evaporative losses. A pond that is about 10m x 10m x 3 m is an ideal size. The pond should have an inlet and an outlet lined with rock to prevent erosion. These features will need to be linked into a larger drainage plan which directs water into the pond, and receives any overflow water. A small settling pit at the inlet will help remove silt, and can be more easily cleaned than the whole pond. The sides of the pond should be sloped for stability.

Table 2. Spatial temporal variation in EC of groundwater due to recharging.

Stage of sampling	Month (year)	Low land coastal area (Ghed)	Distance from seacoast (km) < 10	10-20	>20	Mean
Before recharging	(May 1995)	8.33	5.17	1.62	1.50	2.80
After recharging	(October 1995)	5.29 (36.5)	4.14 (20.0)	1.28 (20.8)	1.34 (10.9)	2.28 (18.2)
After one year of researching	(May 1996)	4.20 (49.6)	3.44 (33.5)	1.20 (25.9)	1.45 (3.6)	1.90 (32.1)

Note: Figures in parenthesis indicate per cent decrease in salinity
Source: Vadher and Gundalia, 1999

Protective irrigation

Protective/supplemental irrigation at times becomes essential for survival of crops in drought prone areas with undependable and erratic rainfall. To accomplish this, excess rainwater has to be conserved/stored in soil profiles and in different storage structures (Table 3).

Table 3. Protective irrigation in *kharif* groundnut

Treatments	Yield (q/ha)		Net ICBR
	Pod	Haulm	
Control (No irrigation)	4.10	16.86	
Flood irrigation	7.31	25.52	1:2.28
Furrow irrigation	6.63	23.66	1:1.68
Alternate furrow irrigation	5.83	21.10	1:0.77
CD (P=0.05)	0.12	1.53	

Source: Malavia *et al.* (1999)

In-situ water harvesting

This technique involves the collection and storage of rainwater in the soil profile by intercepting the run off. Prolonged retention of rainwater on the land surface increases the amount of water entering the soil. The effective methods of *in-situ* water harvesting are summer ploughing, broad bed and furrows, ridges and furrows, random tie ridging, compartmental bunding etc.*In-situ* moisture conservation does not confine to land shaping carried out during cropping season, it encompasses off season tillage, contour farming etc.

Off season tillage or summer ploughing

Proper off season tillage maintains higher stored moisture and thereby secures optimum stand. It is done either by the country plough or by blade harrow during non-crop season after the harvest of *kharif* crop depending on the amount of rainfall. Essentially it is meant to open the soil for more water intake with rains.

In dry farming, the soil becomes vulnerable for hardness when kept fallow during summer months. At the instance of rainfall, the raindrops beat the top surface of soil and make them split and cause heavy loss of top soil transported along with the runoff waters. To prevent loss of top soil and run off ploughing needs to be done during summer by using the available summer showers. This helps the soil to absorb the rains during monsoons and conserve the same as soil moisture for crop growth.

Deep ploughing

Deep ploughing is taken up to break hard pan and also improves physical characteristics of black soils. Deep ploughing has to be done to a depth of 22 cm (tractor plough) in Vertisols which will eradicate pernicious weeds and results in higher crop yields. This may be practised once in 3 years (Table 4).

Table 4. Effect of tillage practices on yield of groundnut.

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)
CT (cultivator + blade harrowing)	862	1,828
Ploughing followed by CT	914	1,913
Tillage through rotavator	852	1,751
CT + subsoiling between rows	902	1,900
CT + broad bed and furrow	1,078	2,035
No tillage	709	1,652
CD (P=0.05)	171	234

Source: Anon. (2008)

Chisel ploughing

To break the hard pan in the sub soil and to allow easy infiltration of rain water into the sub soil, chisel ploughing is recommended at least once in three years.

Subsoiling: Soil compaction is a common problem in dryland farming. This can be further aggravated by presence of hard pan or plough pan in subsoil, which restrict infiltration and storage of rainwater as well as root penetration. Non-inversion tillage like sub-soiling decrease bulk density and increase infiltration of rainwater into soil, reduce runoff losses and thereby increase moisture storage in soil profile and root proliferation. This method consists of breaking with a sub-soiler the hard and impermeable subsoil to conserve more rain-water by improving the physical conditions of a soil. This operation, which does not involve soil inversion and promotes greater moisture penetration into the soil, reduces both run-off and soil erosion. The sub-soiler is worked through the soil at a depth of 30-60 cm at a spacing of 90-180 cm (Tables 5 and 6).

Contour farming: When tillage to harvest done on contour, there is less run off and soil loss. Each ridge acts as a barrier and each furrow acts as a minuscule reservoir, their cumulative effect being significant in maintaining the natural resources namely soil and rain water (Table 7).

Across slope cultivation: Even if contour cultivation is not possible, flat sowing across the slope would be an effective next best alternative. In addition to more conservation of moisture, tillage across the slope would consume

Table 5. Effect of moisture conservation practices on yield of groundnut and net returns

Treatments	Pod yield (t/ha)	Net returns (Rs/ha)
Flat bed	1.423	20.06
Alternate between row sub-soiling	1.545	21.91
Between row sub-soiling	1.740	25.54
In row sub-soiling	1.564	21.81
Broad bed and furrow	1.713	24.83
CD (P=0.05)	0.116	2.30

Source: Vaghasia *et al.* (2007)

Table 6. Effect of moisture conservation practices on yield of pigeonpea and net returns

Treatments	Seed yield (t/ha)	Net returns (x10^3Rs/ha)
Flat bed	1.233	13.84
Alternate between row sub-soiling	1.286	14.34
Between row sub-soiling	1.318	14.46
In row sub-soiling	1.452	16.88
Broad bed and furrow	1.463	17.06
CD (P=0.05)	0.095	1.70

Source: Patoliya, (2006)

less draft energy as compared to up and down cultivation.

Compartmental bunding: Compartmental bunds are suitable for fairly leveled lands with slope < 1% in low rainfall areas. The size of the compartment and strength of the bund depends on the slope and nature of the soil. For annual crops, the recommended size of the compartment is 40 m^2 in black soils. Compartmental bunds, converting the inter-bund area into square parcels of 10 m x 10 m or 15 m x 15 m are useful for temporary impounding of water for improving the moisture status of the soil. These are constructed using bund formers or bullock drawn soil turning ploughs. Here bunding need not be done with a sense of urgency and it can be formed 1 or 2 days after sowing depending on the crop and the cost involved is also less as only bund former is used for forming large sized beds. In places where *kharif* fallowing is a practice, compartmental bunds are built to enhance enough rain water inventory in the soil profile for raising *rabi* crops on the conserved moisture (Vishnumurthy, 1999).

Ridging: In Alfisols for wide spaced crops like sorghum, flat sowing followed by ridging is more useful. The ridge and furrow with earthing up was found suitable for rainfed groundnut at Targhadia (Table 8).

*Tied ridging:*This method is known as furrow blocking, furrow damming, furrow diking and basin listing. The principle is to increase surface storage by first making ridges and furrows, then damming the furrows with small ties. Tied ridges would decrease the run off and increase the storage. Tied ridging should satisfy both storage and drainage of rain-water depending upon the quantum of rains in a year and this could be accomplished by having low ties.

Dead furrows: Dead furrows (idle furrow) are laid across the land slope in rolling lands to intercept the run-off. The spacing between dead furrows varies from 2 to 5 m or 4 to 7 crop rows. This system worked well with Alfisols.

Ridges and furrows: Proper inter-terrace management is essential for soil moisture conservation. Ridges and furrows method of planting has shown to improve the yields and income (Table 9).

Broad bed and furrows (BBF): It implies shaping of land into alternate beds and furrows. This technique specifically suits Vertisols. Generally speaking, the depth of each furrow is kept 15 cm whereas inter-furrows spacing is maintained at 150 cm (bed size 100 cm and furrow size 50 cm). Peak rate of runoff and infiltration determine the length of furrows. Adoption of this technology, however, calls for provision of a BBF former or similar costly farm implements. In areas where the slope is moderate (1-3%), formation of Broadbed and furrow (BBF) is suitable. Nor-

Table 7. Effect of vegetative barrier on cotton cultivation with set row and contour farming (1996-98)

Treatment	Cotton yield (q/ha) Watershed		Soil moisture content (%)	
	Vaghela	Limdi		
Set row	7.50	7.80	19.50	20.00
Set row + vegetative barrier	8.00	8.50	24.00	25.00
Contour farming	8.00	8.20	21.50	22.00
Contour farming + vegetative barrier	8.50	10.00	25.50	26.50
CD (P=0.05)	0.87	0.65		

Source: Sharma *et al.* (2000)

Table 8. Yield of groundnut and economics of various moisture conservation practices.

Treatments	Yield (q/ha)		Gross Income (Rs/ha)	Cost of operation (Rs/ha)	Net return (Rs/ha)
	Pod	Haulm			
Flat sowing	4.60	14.53	6,278	6,230	49
Furrow after every third row	5.03	15.02	6,746	6,330	417
Ridge and furrow with earthing up	5.31	16.61	7,216	6,610	606
Interculturing with earthing up	5.00	16.53	6,906	6,530	376

Source: Yusufzai *et al.*, (1997)

Table 9. Groundnut yield and economics of water conservation practices.

Treatments	Yield (kg/ha) Pod	Yield (kg/ha) Haulm	Income (Rs/ha)	Additional return/ha than farmers method
Flat sowing	308	910	4,118	
Vegetative barriers	341	1,016	4,571	452
Ridge and furrow	436	1,223	5,749	1,630
Contour sowing	371	1,076	4,386	817
Trench-cum-mulching	354	1,047	4,736	617
Compartmental bunding	399	1,145	5,494	1,175

Source: Yusufzai *et al.* (1997)

mally, the width of the broad bed is kept at 120 cm and the width of the furrows of 30 cm. This practice is suitable in areas where rainfall is moderate to high. Experiments on cultivators' field in Junagadh district indicated that conventional tillage was found superior to reduced tillage, while BBF was found beneficial for cotton (Table 10) and castor (Table 11) as compared to flat bed.

Table 10. Effect of tillage and land configuration on cotton yield.

Treatments	Seed cotton yield (kg/ha)	Stalk yield (kg/ha)
Tillage		
Conventional tillage	447	34
Reduced tillage	417	33
CD (P=0.05)	14	NS
Land configuration		
Flat bed	403	32
Broad bed and furrow	461	35
CD (P=0.05)	14	2

Source: Khanpara *et al.* (2003)

Table 11. Effect of moisture conservation practices on yield of castor and net returns.

Treatments	Seed yield (kg/ha)	Stalk yield (kg/ha)	Net returns (Rs/ha)
Flat bed	1,233	1,650	13,836
Alternate between row sub-soiling	1,286	1,712	14,340
Between row sub-soiling	1,318	1,750	14,461
In row sub-soiling	1,452	1,929	16,879
Broad bed and furrow	1,463	1,930	17,059
CD (P=0.05)	0.095	0.103	1,698

Source: Mathukia and Khanpara, (2006)

Vegetative hedge: Vetiver, *Cenchrus* are found suitable for vegetative hedges under rainfed situation. Vetiver slips are to be planted within 24 hr of uprooting and root dipping either in *Azospirillum* or in 5% glucose solution gives better establishment. Vetiver slips are to be planted at 15-20 cm spacing in zig zag manner for effective soil moisture conservation and higher yield.

Live bunds: In place of mechanical or earthen structures, it has been found that live bunds consisting of Vetiver has shown promise in certain areas i.e. in sub-humid areas. But it was found susceptible to termite attack, *Striga* incidence and *Rhizoctonia* diseases. Therefore, *khus* bunds were not successful except in Vertisols. Alternate vegetative materials are being tested in some locations viz., subabul, nasegrass, lemongrass, *Cenchrus ciliaris*, *Gliricidia* and *Aristida* grass. However, live bunds were found promising in recent times when supported by small section bund.

Mulching: It protects soil against beating action of rain drops. It also facilitates rainwater absorption by soil. Surface mulching immediately after sowing is an effective means of controlling runoff and soil loss on cultivated sloping lands. To minimise evaporation from soil surface, dry soil mulch is created simply by stirring the soil with the interculturing implements. It reduces the upper movement of water in the soil surface. Regular intercultivation will help to create soil mulch and thus reduce the evaporation loss of water from soil. They reduce evaporation, soil moisture depletion and increase the yield. Spreading plastic sheets or organic mulches on soil surface in interspace or incorporating stubbles in the soil will act as mulch to reduce the evaporation losses (Table 12 and Fig. 1). Subsurface mulches along contour ditches/

Table 12. Effect of mulching on growth and yield of guava and soil moisture content.

Treatments	Plant height (cm)	Yield (kg/plant)	Soil moisture content (%)
Soil mulch	418	26.0	17.31
Straw mulch	355	27.0	20.94
Stone mulch	319	25.0	18.50
No mulch	344	23.0	15.00
CD (P=0.05)	NS		1.71

Source: Sharma *et al.* (2000)

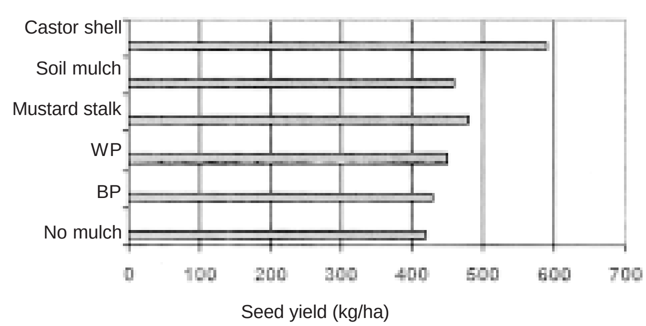

Fig. 1. Effect of mulching on seed yield of castor (Patel *et al.* 1999)

trenches in hilly areas help intercept and store high amount of moisture.

Anti-evaporants: Nearly 50-60% of water is lost through evaporation. Anti-evaporants are used to reduce the evaporation from the soil surface and also water-bodies. Straw, sawdust, wood bark etc. are used to arrest the evaporation from soil surface. Hexadecanol, a long-chain alcohol is also used to arrest the evaporation from soil surface. This chemical is resistant to microbial activity and degradation. It remains in the soil active for more than a year. Further it increases the aggregate stability. The evaporation from free water surface, farm ponds, lakes etc. can be reduced by wax emulsions, free fatty acids. Recent studies indicated that plastic or rubber floats can reduce the evaporation by 80%.

*Anti-transpirants:*Approximately 99% of the water taken up by the plant root is transpired to the atmosphere through stomata. An anti-transpirant is a substance that is applied to transpiring plant surface with the aim of reducing water loss due to transpiration. The other benefits of anti-transpirants are increasing the water-use efficiency, maintaining of turgor pressure etc. There are 4 types of ant-transpirants: *stomatal closure type* (e.g. phenyl mercuric acetate, PMA, atrazine, non-enyl succinic acid, alkenyl succinic acid), *film forming type* (emulsion of plastic, wax, folicot), *reflectants* (kaolin, lime) and *growth retardants* (Cycocel). Anti-transpirants viz., PMA at 0.1% reduce the transpiration by closing the stomata for 2-3 days when sprayed on the leaves. Film forming anti-transpirants produce an external physical barrier to retard the escape of water vapour. Another approach to reduce the transpiration rate is by coating the leaf surface with white reflecting materials. Thus white wash at 2% (20 g of calcium oxide/ litre of water) or kaolinite at 3% helps to lower the leaf temperature and reduce the transpiration when applied on foliage. Growth retardants reduce the total surface area by reducing the shoot growth, below the ground level, root growth is arrested e.g. 30-40% transpiration can be controlled by cycocel.

Windbreak and shelterbelt: In arid and semi-arid regions, the hot winds dry the soil surface and create vapour pressure gradient and continuous vapourisation takes place. So, to cut down this process, shelterbelt is used. It is the practice of growing one or multi rows of trees/shrubs or other plants across the wind direction either in the field or on field boundaries to reduce the wind effect and to reduce the surface wind velocity. The important characteristics of shelterbelt are longer windbreaks are more effective than shorter. For better effect the tall plants should be in the middle of the rows and shorter plants on both sides. To decrease the wind velocity throughout the season, include evergreen and deciduous crops/trees. In drylands, the tree species used as shelterbelt are Cassia siamea, *Prosopis specigera*, *Eucalyptus*, *Casuarina*, *Tamarindus indica* etc.

Intercropping: Intercropping is an insurance against the vagaries of the monsoon. Experiments conducted at Targhadia revealed that intercropping a row of castor after every 3 rows of groundnut increased yield and return (Table 13).

Table 13. Effect of cropping systems on pod equivalent yield of groundnut and their with economics.

Treatment	Pod equiv. yield (q/ha)	Gross return (Rs/ha)	Net ICBR for each treatment
Sole groundnut	6.55	3,111	-
Sole castor	13.20	6,270	-
Sole pigeonpea	5.29	2,513	-
Groundnut + castor (3:1)	12.43	5,904	1:4.39
Groundnut + pigeonpea (3:1)	7.89	3,748	1:0.95
Groundnut + castor (6:1)	11.42	5,424	1:3.29
Groundnut + pigeonpea (6:1)	7.34	3,486	-1:0.56
CD (P=0.05)	2.52		

Source: Yusufzai *et al* (1997)

Alley cropping: In this arable food crops are grown in the alleys formed by hedgerows of perennial trees or shrubs. The best plants for this are subabul and *Glyricidia* because they grow well in degraded soils. This ensures provision of fodder and green manure and rehabilitates degraded land through soil and moisture conservation. Results of an experiment conducted at Targhadia revealed that groundnut grown in alley of *Glyricidia* at 9.6 m was found advantageous for yield and moisture conservation (Table 14).

Table 14. Effect of different alley widths on pod yield of groundnut.

Alley width (m)	Pod yield (t/ha)	Haulm yield (t/ha)	Soil moisture content (%)
6.0	1.030	3.186	34.64
7.8	1.117	3.321	32.54
9.6	1.180	3.481	33.45
CD (P=0.05)	0.103	0.208	1.36

Source: Anon. (2006)

Soil amendments and soil conditioners: A soil conditioner, also called a soil amendment is a material added to soil to improve plant growth and health. The type of conditioner added depends on the current soil composition, climate, and the type of plant. Some soils lack nutrients necessary for proper plant growth and others hold too much or too little water. A conditioner or a combination of conditioners corrects the soil's deficiencies. Lime is used to make soil less acidic. Fertilizers, such as peat, manure,

Table 15. Seed cotton yield as influenced by gypsum application.

Gypsum application (t/ha)	Seed cotton yield (t/ha)
0	1.862
5	2.166
10	2.383
15	2.479
CD (P=0.05)	0.479

Source: Sharma *et al.* (2000)

Table 16. Effect of Jalshakti on yield of bidi tobacco.

Jalshakti (root dipping)	Leaf yield (t/ha)
Water	1.68
Jalshakti 0.75	1.75
Jalshakti 1.50	1.87
CD (P=0.05)	0.18

Source: Upadhyay *et al.* (1999)

anaerobic digestate or compost add depleted plant nutrients. Materials viz., clay, vermiculite, hydrogel, and shredded bark will make soil hold more water. Gypsum releases nutrients and improves soil structure. Sometimes a soil inoculant is added for legumes. Unless clay is incorporated into a healthy crumb structure, water may bond to it too strongly to be available to plant roots. Application of tank silt during summer will improve the structure of soil and thus improve water-holding capacity of soil. Experiments conducted in watershed area revealed that application of gypsum significantly increased seed cotton yield (Table 15). Similarly, root dipping in Jalshakti significantly increased leaf yield of bidi tobacco at Anand (Table 16).

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