Ind. Jn. of Agri.Econ.
Vol.63, No.3, July-Sept. 2008

SUBJECT III
RAINFED AGRICULTURE

Strengthening Indian Agriculture through Dryland Farming: Need for Reforms

R. Ramakrishna and D. Tata Rao*

I

INTRODUCTION

Performance of agriculture plays a major role in the progress of the economy in achieving the developmental goals of eradication of poverty, faster and sustainable growth and modernisation of society. Agriculture sector is the backbone of the country's development and lifeline for 65 per cent of the population in rural areas and approximately more than 58 per cent of the population are still dependent on agriculture for their livelihood. Besides this to achieve an ambitious rate of growth for the country of as high as 9-10 per cent in the Eleventh Five Year Plan, the country needs a strong pull-up support to agriculture sector which should grow at least at the rate of 4 per cent per annum, all the more since in 2005-06 the growth in agriculture was merely 2.2 per cent which is expected to go even negative next year (Mittal, 2007). The performance of Indian agriculture has gone through three phases of growth – area based growth up to the late sixties; yield based growth up to the early eighties. It is the third phase which provides interesting clues to a farmer's behaviour in dry land agriculture, the strength of support which he derives from the policy regime and the capabilities of the policy to provide the thrust needed for the development of dryland agriculture.

The dry land agriculture plays an important role in the progress of agriculture in the Indian economy. In India 68 per cent of total net sown area (136.8 mha) comes under dry lands spread over 177 districts. Dry land crops account for 48 per cent area under food crops and 68 per cent area under non-food crops. Nearly 50 per cent of the total rural work force and 60 per cent of livestock in the country are concentrated in the dry districts (DHAN Foundation, 2006). In general, the economic policies of developing countries in past years have had negative effects on development in the dry land regions. Development strategies have shifted resources away from dry land to irrigated production and from rural to urban areas. Since dry land farmers are poorer and politically less influential, the effects of adverse macroeconomic policies fall disproportionately on them in spite of the fact that they are often the primary producers of food crops.

*Professor and Head, and Doctoral Fellow, respectively, Department of Applied Economics, Andhra University, Visakhapatnam-530 003 (Andhra Pradesh).

II

PERFORMANCE OF INDIAN AGRICULTURE

Agriculture being constrained by availability of land, the productivity remains the most crucial factor based on which is the future of India's food security. Long term food security goal can only be attained if there is sustainable agriculture. At the farmers' level, sustainability concerns are being expressed that the input levels have to be continuously increased in order to maintain the yield at the old level. This poses a threat to the economic viability and sustainability of crop production. A sustainable farming system is a system in which the natural resources are managed so that potential yield and the stock of natural resources do not decline over time (Kumar and Mittal, 2006). The performance of agriculture, however, was not satisfactory. The share of agricultural sector in gross domestic product (GDP) has declined from 26.2 per cent in 2000-01 to 21.7 per cent in 2005-06 (Table 1).

TABLE 1. ANNUAL GROWTH RATE AND SHARE OF AGRICULTURE AND ALLIED SECTORS IN GDP AT 1999-2000 PRICES

(per cent)

Year (1)	Annual growth rate (2)	Share in GDP (3)
2000-01	0.0	26.2
2001-02	5.9	26.2
2002-03	-5.9	23.8
2003-04	9.3	23.9
2004-05	0.6	22.4
2005-06	5.8	21.7

Source: *Economic Survey, 2006-07.*

The All-India area, production and yield of food grains along with percentage coverage under irrigation are presented in Table 2. The area under foodgrains has increased from 97mh to 128mh during 1950-51 and 1990-91. And later it has declined to 124mh in 2003-04. The production of foodgrains has increased from 51mt to 196mt during 1950-51 and 2000-01 and it was stagnant from 2000-01 onwards. The yield per hectare has increased from 522 kgs in 1950-51 to 1734 kgs in 2001-02 and later it was stagnant. The All-India area, production and yield of rice, wheat, cereals, pulses, oilseeds and cotton are presented in Table 3. The production of rice has increased from 21mt to 87mt during 1950-51 and 2003-04. The yield per hectare has also increased from 668 kgs in 1950-51 to 2051 kgs in 2003-04. The production of wheat also increased from 6mt to 72mt during 1950-51 and 2003-04 owing to improvement in yield from 663 kg per hectare to 2707 kg per hectare.

TABLE 2. ALL-INDIA AREA, PRODUCTION AND YIELD OF FOODGRAINS FROM 1950-51 TO 2003-04 ALONGWITH PERCENTAGE COVERAGE UNDER IRRIGATION

(*area-million hectares*)
(*production- million tonnes*)
(*yield-kg/hectare*)

Year (1)	Area (2)	Production (3)	Yield (4)	Per cent coverage under irrigation (5)
1950-51	97.32	50.82	522	18.1
1960-61	115.58	82.02	710	19.1
1970-71	124.32	108.42	872	24.1
1980-81	126.67	129.59	1023	29.7
1990-91	127.84	176.39	1380	35.1
2000-01	121.05	196.81	1626	43.4
2001-02	122.78	212.85	1734	N.A.
2002-03	111.50	174.19	1562	N.A.
2003-04	124.24	212.05	1707	N.A.

Source: Central Statistical Organisation, New Delhi.

TABLE 3. ALL-INDIA AREA, PRODUCTION AND YIELD OF RICE FROM 1950-51 TO 2003-04 ALONGWITH PERCENTAGE COVERAGE UNDER IRRIGATION

(area-million hectares)
(production- million tonnes)
(yield-kg/hectare)

Year (1)	Area (2)	Production (3)	Yield (4)	Per cent coverage under irrigation (5)
		RICE		
1950-51	30.81	20.58	668	31.7
1960-61	34.13	34.58	1013	36.8
1970-71	37.59	42.22	1123	38.4
1980-81	40.15	53.63	1336	40.7
1990-91	42.69	74.29	1740	45.5
2000-01	44.71	84.98	1901	53.6
2001-02	44.90	93.34	2079	N.A.
2002-03	40.28	72.65	1804	N.A.
2003-04	42.41	87.00	2051	N.A.
		WHEAT		
1950-51	9.75	6.46	663	34.0
1960-61	12.93	11.00	851	32.7
1970-71	18.24	23.83	1307	54.3
1980-81	22.28	36.31	1630	76.5
1990-91	24.17	55.14	2281	81.1
2000-01	25.73	69.68	2708	88.1
2001-02	26.34	72.77	2762	N.A.
2002-03	24.86	65.10	2619	N.A.
2003-04	26.62	72.06	2707	N.A.

(Contd.)

TABLE 3. *(CONCLD.)*

Year (1)	Area (2)	Production (3)	Yield (4)	Per cent coverage under irrigation (5)
		COARSE CEREALS		
1950-51	37.67	15.38	408	7.9
1960-61	44.96	23.74	528	7.7
1970-71	45.95	30.55	665	8.3
1980-81	41.78	29.02	695	9.2
1990-91	36.32	32.70	900	9.0
2000-01	30.26	31.08	1027	12.5
2001-02	29.52	33.38	1131	N.A.
2002-03	26.31	25.30	962	N.A.
2003-04	30.76	37.76	1228	N.A.
		PULSES		
1950-51	19.09	8.41	441	9.4
1960-61	23.56	12.70	539	8.0
1970-71	22.54	11.82	524	8.8
1980-81	22.46	10.63	473	9.0
1990-91	24.66	14.26	578	10.5
2000-01	20.35	11.08	544	12.5
2001-02	22.01	13.37	607	N.A.
2002-03	20.05	11.14	556	N.A.
2003-04	24.45	15.24	623	N.A.
		OILSEEDS		
1950-51	10.73	5.16	481	N.A.
1960-61	13.77	6.98	507	3.3
1970-71	16.64	9.63	579	7.4
1980-81	17.60	9.37	532	14.5
1990-91	24.15	18.61	771	22.9
2000-01	22.77	18.44	810	23.0
2001-02	22.64	20.66	913	N.A.
2002-03	21.22	15.06	710	N.A.
2003-04	23.44	25.14	1072	N.A.
		COTTON		
1950-51	5.88	3.04	88	8.2
1960-61	7.61	5.60	125	12.7
1970-71	7.61	4.76	106	17.3
1980-81	7.82	7.01	152	27.3
1990-91	7.44	9.84	225	32.9
2000-01	8.53	9.52	190	34.3
2001-02	9.13	10.00	186	N.A.
2002-03	7.67	8.72	193	N.A.
2003-04	7.64	13.79	307	N.A.

Source: Central Statistical Organisation, New Delhi.

The area under cereals has declined from 38mh to 31mh during 1950-51 and 2003-04 but the production of cereals increased from 15mt to 38mt during the same period owing to improvement in yield from 408 kgs per hectare to 1228 kgs per hectare. The area under pulses increased from 19mh to 24mh during 1950-51 and 2003-04. The production of pulses has increased from 8mt to 15mt during the same period owing to improvement in yield from 441 kgs per hectare to 623 kgs per hectare. In case of oilseeds the production of oilseeds increased from 5mt to 25mt during 1950-51 and 2003-04 owing to improvement in yield from 481 kgs per hectare to 1072 kgs per hectare. The area under cotton crops increased marginally from 6mh to 8mh during 1950-51 and 2003-04. The production of cotton increased from 3mt to 14mt during the same period owing to improvement in yield from 88 kgs per hectare to 307 kgs per hectare.

The data regarding net availability of food grains for all important crops in India and per capita food grains during 1951-2003 are presented in Tables 4-5. The per capita foodgrains increased from 144.1 in 1951 to 159.2 in 2003 but it is marginal. The achievements of production of almost all crops was lower than the target fixed during 2002-03 and 2003-04 (Table 6). Low yield per unit area across almost all crops has become a regular feature of Indian agriculture (Table 7). For example, though India accounted for 21.8 per cent of global paddy production, the estimated yield per hectare in 2004-05 was less than that in Korea and Japan, and only about a third of that in Egypt, which had the highest yield level in the reference year. Similarly, in wheat, while India accounted for 12 per cent of the global average, it was less than a third of the highest level estimated for the UK in 2004-05. For coarse grains and major oilseeds, Indian yields are a third and 46 per cent, respectively, of the global average. In cotton, the situation is slightly better with Indian yields at 63 per cent of the global average. While agro-climatic conditions prevailing in countries may partly account for the differences in yield levels, nonetheless, for major food as well as commercial crops, there is tremendous scope for increasing yield levels with technological breakthroughs. The distribution of irrigated area according to source of irrigation by major size-classes of operational holdings of all size groups is presented in Table 8.

TABLE 4. NET AVAILABILITY OF FOODGRAINS IN INDIA FROM 1951 TO 2003

(per day)

Year (1)	Rice (2)	Wheat (3)	Other cereals (4)	Cereals (5)	Gram (6)	Pulses (7)	Foodgrains (8)
1951	158.9	65.7	109.6	334.2	22.5	60.7	394.9
1961	201.1	79.1	119.5	399.7	30.2	69.0	468.7
1971	192.6	103.6	121.4	417.6	20.0	51.2	468.8
1981	197.8	129.6	89.9	417.3	13.4	37.5	454.8
1991	221.7	166.8	80.0	468.5	13.4	41.6	510.1
2001	190.5	135.8	56.2	386.2	8.0	30.0	416.2
2002(P)	228.1	164.4	64.7	457.3	10.7	35.0	492.2
2003(P)	183.4	178.9	44.9	407.1	8.3	29.1	436.3

Source: Central Statistical Organisation, New Delhi.

TABLE 5. NET AVAILABILITY OF FOODGRAINS IN INDIA FROM 1951 TO 2003

(per annum)

Year (1)	Rice (2)	Wheat (3)	Other Cereals (4)	Cereals (5)	Gram (6)	Pulses (7)	Per capital foodgrains (8)
1951	58.0	24.0	40.0	122.0	8.2	22.1	144.1
1961	73.4	28.9	43.6	145.9	11.0	25.2	171.1
1971	70.3	37.8	44.3	152.4	7.3	18.7	171.1
1981	72.2	47.3	32.8	152.3	4.9	13.7	166.0
1991	80.9	60.0	29.2	171.0	4.9	15.2	186.2
2001	69.5	49.6	20.5	141.0	2.9	10.9	151.9
2002(P)	83.1	60.0	23.6	166.9	3.9	12.8	179.7
2003(P)	66.9	65.3	16.4	148.6	3.0	10.6	159.2

Source: Central Statistical Organisation, New Delhi.

TABLE 6. TARGETS AND ACHIEVEMENTS OF PRODUCTION OF MAJOR CROPS DURING 2002-03 AND 2003-04

	2002-03		2003-04	
Crop (1)	Targets (2)	Achievements (3)	Targets (4)	Achievements* (5)
Rice	93.00	72.66	93.00	87.00
Wheat	78.00	65.10	78.00	72.06
Coarse cereals	33.00	25.29	34.00	37.76
Pulses	16.00	11.14	15.00	15.23
Foodgrains	220.00	174.19	220.00	212.05
Oilseeds	27.00	15.06	24.70	25.14
Sugarcane	320.00	281.58	320.00	236.18
Cotton #	15.00	8.72	15.00	13.79
Jute and mesta@	12.00	11.38	12.00	11.20

Source: Central Statistical Organisation, New Delhi.

million bales of 170 kg. each; @million bales of 180 kg. each; * Advance Estimates as on 05.08.2004.

TABLE 7. INTERNATIONAL COMPARISONS OF YIELD OF SELECTED COMMODITIES–2004-05

(metric tonnes/ hectare)

(1)	(2)	(3)	(4)	(5)	(6)
Rice/paddy		Wheat		Maize	
Egypt	9.8	China	4.25	U.S.A	9.15
India	2.9	France	7.58	France	7.56
Japan	6.42	India	2.71	India	1.18
Myanmar	2.43	Iran	2.06	Germany	6.69
Thailand	6.73	Pakistan	2.37	Philippines	2.1
Korea	2.63	U.K	7.77	China	4.9
U.S.A.	7.83	Australia	1.64		
World	3.96	World	2.87	World	3.38
(7)	(8)	(9)	(10)		
Cotton		Major oilseeds			
China	11.10	Argentina	2.51		
U.S.A	9.58	Brazil	2.48		
Uzbekistan	7.98	China	2.05		
India	4.64	India	0.86		
Brazil	10.96	Germany	4.07		
Pakistan	7.60	U.S.A	2.61		
		Nigeria	1.04		
World	7.33	World	1.86		

Source: Ministry of Agriculture and Co-operation, Government of India, New Delhi.

TABLE 8. DISTRIBUTION OF IRRIGATED AREA ACCORDING TO SOURCE OF IRRIGATION BY MAJOR SIZE-CLASSES OF OPERATIONAL HOLDINGS OF ALL SIZE GROUPS, 1990-91

('000 *hectares*)

Size class (1)	Canals (2)	Tanks (3)	Wells (4)	Tubewells (5)	Others (6)	Total (7)
Marginal	3348	940	1015	3319	835	9457
Small	3061	682	1611	3013	717	9085
Semi-medium	3645	654	2311	3555	806	10971
Medium	3851	503	2845	3442	644	11286
Large	1762	178	1305	1364	296	4905
Total	15667	2957	9088	14694	3297	45704

Source: Central Statistical Organisation, New Delhi.

The performance indicators seen above show that in any given year there would be farmers who end up in distress making losses. This is not unusual in agriculture. However, in drought-prone agriculture such distress can be pervasive and cumulative in certain areas and sections of farmers, though, it may not show up in the average performance of farmers in a large state. The transition from subsistence farming to production for market is hardly likely to be smooth in drought-prone agriculture, particularly for those who have been weak and vulnerable for generations. The cycle of distress usually begins with a sharp rise in borrowing followed by deepening distress owing to absence of support mechanisms culminating, finally, in the loss of land. Even if the farmer is rescued during one cycle, he has to pass through a succession of them and could succumb later.

III

CONSTRAINTS IN DRY LAND AGRICULTURE

Despite concerted efforts made in past to improve the productivity by transferring improved technologies, gains in terms of higher yield and income have not been spectacular due to associated risks like aberrant weather, land degradation and poor socio-economic base of the farmers. Although a major constraint to dry land agriculture is deficient water, hazards such as insects, diseases, hair, high winds and intensive rains can destroy crops in a matter of minutes or days. Farmers in dry land regions are often resource-poor and these regions are usually of low priority when national resources are allocated. There are three constraints in dry land agriculture—physical, technological, institutional - infrastructural and socio-economic (Rajakumar, *et al.*, 2007).

Physical Constraints

Agro-climatic conditions: In dry land areas, the environment is often more yield-limiting than even the genetic potential of the crops. The dominant features of rainfall in dry land regions are its limited quantum, temporal and spatial variability and unpredictability. There are more years below the mean than above the mean, with the degree of skewness inversely related to amount of rainfall. Rainfall distribution is also very irregular. Rainfall intensity is extremely variable, and high intensity events even when the quantum is relatively low, can result in substantial run-off and soil erosion, so a crop management system must protect the soil resource. The temperature extremes also limit productivity in many dry land areas.

Wind Erosion: Wind erosion is one of the geomorphologic processes that affects the processes in semi-arid regions and influences the very future of civilisation. Soil is essential to sustain mankind, but soil can be rendered infertile by the complete removal of top soil or selected removal of soil fines by wind. As soil erosion becomes increasingly severe, alternative methods of control compatible with farming practices must be employed.

Water Erosion: Water erosion at some level is inevitable. Accelerated erosion reflects the activity of man. It occurs because of cultivation of sloppy lands or vegetation alteration caused by a concentrate of domesticated animals. Genetically accelerated erosion is detrimental. It results in movement of top soil from hill slopes to valley bottoms or to streams and reservoirs. Sub-soil is usually less hospitable to plant growth than top soil because of a lack of nutrients and lower available water holding capacity. To avoid water erosion reduced tillage or no till systems were developed.

Soil Characteristics: Soils in the dry land regions of the world range from sandy, shallow, low-fertility soils to highly productive, medium to fine textured, deep soils, but the majority of dry land soils have serious problems. Soil characteristics are strongly influenced by the climate in which soils develop, and the interactions of these characteristics with current climatic conditions are a major consideration in understanding the productivity of dry land soils. Other soil problems such as surface soil hardening, compaction by tillage implements, susceptibility to water and wind erosion, low fertility, shallowness, hardening, restricted drainage and salinisation also affect crop production.

Physical: Many of the upland soils in the tropical dry land areas are sandy, often gravelly and generally shallow. These factors contribute to a low water holding capacity which makes it more difficult to deal with the detrimental effects of erratic and limited precipitation. Erosion, both wind and water has intensified these constraints. Soil hardening and crusting are very common in dry land soils and result in large amounts of run-off. When water runs off, there is less water available for producing biomass and less input of organic material into the soil, which makes maintenance of good soil physical conditions even more difficult.

Chemical: Soil chemical problems include low inherent fertility, acidity, toxic levels of aluminum or other elements and low nutrient-holding capacity. Essential plant nutrients can be lost through surface run-off, erosion, leaching, and removal of plant materials. Soil acidity resulting in aluminum toxicity is a common chemical problem in dry land soils.

Biological: Restricted biological activity resulting from a sub-optimum soil environment would greatly affect the cycling and transformation of nutrients present in organic form. Biological activity in soils is generally much lower in dry land than in more humid zones. The reasons are apparent – lower organic matter levels and periods of extreme dryness. There is also evidence that the organic matter present in dry land soils is chemically and biologically less stable, because there is less biological turnover of organic matter.

Technological Constraints

Soil Fertility: Low native fertility is a widespread problem on sandy soils and on the lateritic ferruginous (iron-rich), medium textured soils of many countries. The lack of some micronutrients is apparent in specific areas, and these deficiencies will intensify and spread as cropping systems intensify. The interactions between nutrients and water are very pronounced, resulting in inadequate response to additional water at low fertility levels and poor response to nutrient additions if water is not available for plant growth.

Crop Germplasm: Attention for long-term plant breeding programmes for improved drought resistance is warranted, but this effort should be a relatively small part of the overall effort, particularly for developing near-term strategies. Improving germ plasm for disease and insect resistance is another matter of concern and this activity and the development of cultivars that are tolerant to aluminum toxicity resulting from soil acidity are extremely important in dry land regions.

Production Practices: Low crop and animal production in dry land farming is not necessarily the result of a lack of scientific knowledge. The principles of dry land farming are fairly well established and proven practices have been developed for some areas only.

Agronomic Practices: A farmer with limited resources will find it difficult and risky to simultaneously adopt several new techniques that require a shifting of household resources. Moreover, learning a new practice thoroughly may extend over several seasons and have uncertain future payoff. For these reasons, technology adoption often proceeds slowly despite the potential benefits demonstrated at a research level. Choosing the optimum plant population and width of row spacing continues to be one of the most difficult challenges for dry land producers. High or too low plant densities can reduce grain yields because high densities use too much of the available soil water early in the season and low densities does not fully exploit the available soil water for the complete season. The constraints include contour ridging, tied ridges, water harvesting, organic and chemical fertilisers, green manuring, weed control, erosion control practices, agro forestry etc., also.

Mechanisation and Power: Lack of adequate animal and mechanical traction constrains crop production in many dry land regions. The size and complexity of equipments are not economically and socially acceptable to the farmers.

Institutional and Infrastructural Constraints

Credit: A move toward more intensive farming systems significantly raises the cost of production and in dry land areas where moisture supplies are not assured, greatly elevates the risk level of making profit. Better institutions in rural areas are needed to ensure that all segments of the communities have access to credit at affordable terms. Affordable credit must be available to the poor farmer.

Marketing and Distribution: The inability to effectively market the produce limits a farmer's ability to dispose off surplus output and reduces their income earning potential. Transportation systems also improve access to production inputs.

Research and Technology Transfer: In dry land regions, especially in many developing countries, research institutions are woefully inadequate. Too often, the resources allocated to dry lands have been minimal, because primary attention has been focused on irrigated agriculture. Data are often inadequate for analysing the agro-climatology and soil resources and management practices. Good databases are essential for the development of dry land regions.

Fertilisers and Pesticides: The productivity of many dry land soils cannot be increased without raising the fertility level and in controlling pests. Soil fertility can quickly become the limiting factor in crop production and infrastructure is inadequate in many dry land regions to assure the availability of fertilisers and pesticides. Unwise or misguided use of chemical inputs can be very costly and can lead to low efficiency and disenchanted farmers.

Farm Level Knowledge Base: If dry land farmers are to fulfill their role in the development process, they must become better informed about technical and economic matters that affect them. In the past, though the traditional practices were adequate for producing the food and fiber requirements of that population, they cannot serve the current and future needs to support increased numbers of population. Hence, dry land farmers must have a better base of technical knowledge and an understanding of the interactions between their farming practices and current and future physical resources.

Socio-Economic Constraints

Population Growth: Population pressure affects the resource base extensively and intensively. Extensive pressure leads to conversion of grasslands and forests to cropland, with expansion normally progressing into less and less favourable areas.

Land Tenure and Fragmentation: Land ownership patterns in many parts of the world are based on the cultural inheritance traditions and often provide for equal division of agricultural land among heirs. This often results in dividing land into long strips or in small blocks. With small land parcels, use of modern machinery is much more difficult. Often the land division occurs up and down the slope, making it difficult to use sound soil and water conservation practices such as terracing, contouring and other methods of cross-slope farming.

IV

DRY LAND FARMING TECHNIQUES

Dry land farming is the profitable production of crops, without irrigation, of land with a low average or highly variable rainfall (Creswell and Martin, 1993 and 1998).

Increase Water Absorption

Prevent a crust at the soil surface. Probably the greatest deterrent to a high rate of water absorption is the tendency for soils to puddle at the surface and form a seal or crust against water intake.

Reduce the Run-off of Water: To the extent that water logging is not a problem, the run-off of water and its attendant erosion must be stopped.

Reducing the Loss of Soil Moisture

Reducing Soil Evaporation: Water in the soil exists as a continuous film surrounding each grain. As water near the surface evaporates, water is drawn up from below to replace it, thinning the film. When it becomes too thin for plant roots to absorb, wilting occurs.

Reducing Transpiration: All growing plants extract water from the soil and evaporate it from their leaves and stems in a process known as transpiration.

Dry Farming Practices

Dry farming builds upon knowledge of general agriculture but carries out its practices in the light of the significant probability that this year or next will be a drought. The following agricultural practices are discussed with this background:

Bunding: The first essential step in dry farming is bunding. The land is surveyed and level contours determined every hundred feet. For unusual slopes, it is recommended that for every fall of two feet, a bund 18 to 24 inches in height be constructed. Even when land is fairly flat, a 12 inch high bund every 250 feet is still found useful.

Strip Cropping: Strip cropping is a technique that serves to control erosion and increase water absorption thereby maintaining soil fertility and plant response. In effect, it employs several good farming practices such as crop rotation, contour cultivation, stubble mulching, etc.

Summer Fallow: All of the principles of water conservation and utilisation pertaining to dry-farming will not make a crop grow if sufficient rain is not received. Where the soil depth exceeds 18 inches (450 mm), however, it has been shown that it is possible to store water as soil moisture from one year to the next by the use of proper summer fallow techniques.

Mulches: Water easily enters porous soil and, as it seeps downward, becomes absorbed as films of water around the soil grains. These films form a continuous column of water to the surface of the soil. The film tends to remain the same thickness around all the soil grains with which it is in contact. This film of water in the soil is known as the capillary water and is the source of water for the plants. The sun, wind, and dry air will cause evaporation at the surface, thus reducing the thickness of the film at the surface. The thicker films in the sub-soil will rise to equalise the distribution again. This will continue until the films are so thin that the plant roots can draw no further moisture from them. The result is drought.

Stubble mulching - aims at disrupting the soil drying process by protecting the soil surface at all times, either with a growing crop or with crop residues left on the surface during fallows. To be effective, at least one tonne per hectare must cover the surface, and the maximum benefit per unit residue is obtained at about two tonnes per hectare. The benefit may still be obtained at 8 tonnes per hectare.

Dirt Mulching - aims at disrupting the soil drying process with tillage techniques that separate the upper layer of the soil from the lower layers, making the soil moisture film discontinuous. In addition the soil surface is made more receptive to water intake.

Principles of Dirt Mulching:

Ploughing/Tillage Practices: Ploughing, when the soil is in the proper condition, wears the soil into thin layers, and forces the layers past each other. If the soil is too wet when ploughed (especially if it is heavy), the soil crumbs or granules are destroyed, thus puddling or compacting the soil. When the soil is too dry, the soil tends to pulverise and form dust. Ploughing with steep moldboards have the greatest pulverising action upon the soil. The Plough with the less steep moldboard has less tendency to puddle the soil and is of less draft.

Timing of Tillage: Ploughing, like planting, is sensitive to moisture and neither should be done when soil is either too wet or dry. In the arid and semi-arid tropics, proper moisture conditions are likely to occur only at the beginning of the rainy season and should be done on the same day. If possible, planting should immediately following plowing, with seed rows centered on the furrow slices. A crosswise harrowing will cover seeds and close air spaces, thus creating a dirt mulch and keeping out the drying winds. If the crop is then harrowed/cultivated several times during the season, especially after rains, much moisture will be conserved. The proper soil moisture condition for plowing is indicated by a manual soil test.

Depth of Ploughing: Generally speaking, heavy clay soils should be ploughed deeper than light, sandy soils, in order to promote circulation of the air and bacterial activity. Deep ploughing on sandy soils, which are naturally porous and open, tends to disconnect the seed bed from the sub-soil and speeds soil drying by too free a circulation of air in the soil.

Seed Bed Preparation: In general, smaller seeds require a finer, mellower seed bed than larger seeds. Seeds germinate and plants grow more readily on a reasonably fine, well prepared soil than on a coarse, lumpy one, and thorough preparation reduces the work of planting and caring for the crops. It is possible to overdo the preparation of soils. They should be brought to a granular rather than a powder-fine condition for planting.

Planting Density: Limited moisture dictates the necessity for wider row spacing and lower rates of seeding (by one-half to two-thirds) than those used in moisture abundant areas. The resulting reduced plant population provides more moisture and nutrients per plant and thus enhances the possibility of the crop reaching maturity before the supplies are exhausted.

Intertillage/Cultivation: Crops sown in rows can take advantage of intertillage practices which serve three basic functions:

(a) Easy weeding without meticulous hand labor. Weeds compete for moisture and nutrients, thus they should be destroyed while small, before they have grown more than 2 or 3 leaves. If seeds are broadcast, or thickly sown, they can at best only be cultivated manually, a back-breaking task.

(b) Increase the formation of nitrates by bacteria. Cultivation aerates the soil and forms a mulch of dead weeds and stubble on which bacteria operate and form nitrates. Cultivation for this purpose should be undertaken during the early period of plant growth, and should be relatively deep, in the order of 2-3 inches.

. (c) Intertillage conserves moisture by the formation of a dirt mulch as described earlier. It is imperative that cultivation be performed after rainfalls. Even a light rain can re-form capillary connections between the stored soil moisture and the surface of the ground. After a few drying days like that, it is possible for soil moisture to be lower than before the rainfall.

Crop Rotation: One of the first principles of dry farming with regard to cropping practices is that crop rotation as practiced in more humid regions is not necessarily recommended in semi-arid lands. There are five basic reasons why crop rotation should be practiced:

1. *Moisture Conservation*: Any system of crop rotation should be planned with moisture requirements as the main consideration. For a given set of climatic conditions, a crop may be described as either moisture dissipating or conserving. After harvest of a moisture conserving crop, the soil contains more moisture than at planting. This reserve of moisture can help guarantee the succeeding crop.

2. *Pest Control*: Where related crops are successively planted in the same place, viruses, molds, blights, and selective insect pests tend to build up in the soil. Crop rotation that leaves at least two years in between subject plants in the same location will eliminate the abnormal build-up of most such pests for most crops.

3. *Erosion Control*: Plants which are thickly planted or which produce a thick ground cover tend to resist erosion much better than those which are intertilled or tend to be moisture conserving. Loss of soil due to erosion is a significant dry farming problem and erosion controlling crops should be included in a rotation, preferably in a strip cropping mode.

4. *Soil Nutrients and Structure*: When related crops are successively planted, specific soil minerals and nutrients are withdrawn faster than they can be replaced by decay or subsoil movement. This selective depletion wears out the soil quickly. On the other hand, simple rotation of crops makes depletion more uniform so that soils "wear out" more slowly.

5. *Distribution of Labour and Risk*: It is generally advisable for the subsistence farmer to grow all crops in the rotation scheme simultaneously, apportioning to each crop the fraction of fields that it requires. This helps the scheduling and distribution of labour at the bottlenecks (planting, harvesting, etc.) so that the entire crop need not be done simultaneously. There is also a reduced risk of total crop failure and increased variety/nutrition in the diet.

Crop and Variety Selection: Choice of varieties is important. Varieties which have proven excellent in irrigated or high rainfall areas are generally unsuited for dry land conditions. Many attempts at dry land farming have failed, largely due to lack of recognition of the requirements for the variety selection.

V

IMPACT OF POLICY ON DRY LAND FARMING

During the green revolution era, large investments were made on research and development for irrigated agriculture. The promotion of high- yielding variety (HYV) seed, fertiliser, and irrigation technology had a high pay-off and rapid strides of progress were made in food production. But still Indian agriculture is largely dependent on monsoon, the conventional ponds and tanks have become obsolete, the increased demand for water for non- agricultural purposes, over-exploitation of the groundwater has resulted in lowering of the water table. The irrigation potential of the country is 140 million hectares of which only 70 per cent has been exploited (Braun *et al.*, 2005). The slow pace of exploitation of irrigation potential is due to lack of resources in state government and the tendency to spread available resources over few projects (Ahluwalia, 2005). Efficiency in water use is as important as increasing the cultivable area under irrigation. The problems of water logging and soil salinity may develop sooner or later in many irrigation project areas due to over-irrigation and deep percolation and seepage losses in the absence of suitable drainage. The problem is likely to aggravate further in future if proper soil management practices including provision of suitable field irrigation channels and drainage system are not undertaken.

Many programmes have been initiated by the government which requires less investment for water management- rain water harvesting, watershed programmes. But the irony is that the large scale canal irrigation systems are in poor condition, the cost of new schemes are huge and lot of backlog of incomplete schemes are adding to the problems of our irrigation systems (Gulati *et al.,* 2005). The actual performance of the irrigation system in India is much below the required level. Besides propagating the wide use of sprinklers and drip irrigation, the most crucial need is irrigation management. Government agencies and farmers need to work together in this direction. Low water charges encourage highly water-intensive crops at upper end of the canal network leaving the tail end portions starved of water (Ahluwalia, 2005). Efficient irrigation supply through an autonomous body can be initiated as part of the reforms. Along with structural changes, it is necessary to achieve adequate reforms that will be the key for long term sustainability of the irrigation system (Gulati *et al.*, 2005). In addition, a widely debated and accepted strategy for bringing 10 million hectares of new area under irrigation under the Bharat Nirman programme should be developed. The Polavaram Project to be built across the Godavari in Andhra Pradesh is a case in point. Demand management through improved irrigation practices, including sprinkler and drip irrigation, should receive priority attention. A water literacy movement should be launched and regulations developed for sustainable use of ground water as well as for preventing pollution. Seawater farming should be promoted in coastal areas through the cultivation of mangroves, salicornia, casuarinas, and appropriate halophytic plants. The conjunctive use of rain, river, ground, sea, and treated sewage water should become the norm (Swaminathan, 2006).

Huge public and private investment is required to meet the cost of treating rainfed area to ensure optimal use of water. But since mid-1990s the share of private investments has been declining and that of public investment is stagnant owing to rise in subsidies and decline in tax – GDP ratio (Table 9). There is a need to motivate more private investments into the agriculture sector and incentives like tax concessions or benefits can be proposed to them. There is also a strong need of private public partnership, not only to initiate new projects but also to support and maintain the existing public structure. This initiative is quite relevant for development of agricultural research and extension system. A huge research and development infrastructure is in place by the Government of India in the form of institutions of Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs) and Krishi Vigyan Kendras (KVKs). The role of this set-up in research and extension activity is of great importance for the agricultural system. The products produced in the research centres can be marketed commercially to generate additional earnings. In this area the private sector research centres can collaborate for the benefit of the farmers and the country. Besides this programmes of farmers participation in respect of using the traditional technical knowledge and innovative and experimental capability of the farmer for laboratory and field experimental farms need to be taken up. On farm research benefits should be given to such farmers.

TABLE 9. PUBLIC AND PRIVATE INVESTMENT IN AGRICULTURE (1999-2000 PRICES)

Year (1)	Investment in Agriculture (Rs. crores) Public (2)	Private (3)	Total (4)	Investment in agriculture as per cent of GDP (5)
1999-00	17.7	82.3	43473	2.2
2000-01	18.5	81.5	38735	1.9
2001-02	18.6	81.4	47043	2.2
2002-03	17.0	83.0	46823	2.1
2003-04	20.8	79.2	45132	1.9
2004-05	21.1	78.9	48576	1.9
2005-06	24.2	75.8	54539	1.9

Source: Economic Survey, 2006-07; *: Quick estimates.
Figures in parentheses are per cent share in agriculture gross investment.

VI

CONCLUSIONS

Agriculture sector reforms should be initiated on a war-footing, to bring together all the best that is available and make agriculture an organised unit to give farmers the maximum benefits. Turning agriculture into an organised business with the farmer as the entrepreneur should be the key to the second green revolution and for the much desired evergreen revolution in India. Farming should be taken up with the motive of profit making rather than just making a subsistence living. With huge diversity in the number and variety of crops that we produce, variations in agro-climatic conditions, soil type, prevailing inequalities in the state growth levels, it is uttermost essential to implement the plans through micro level initiatives and proper co-ordination between all the stake holders. These issues need to be considered to meet the targets laid out in the Eleventh Plan strategy to raise agricultural output. Therefore, the prevailing policy instruments need to be re-looked at, re-defined, re-written and efficiently implemented to take care of the dry land farming. There is a need to motivate more private investment into the agriculture sector and incentives like tax concessions or benefits can be proposed to them. There is also a strong need for private-public partnership, not only to start new projects but also to support and maintain the existing public structure.

REFERENCES

Ahluwalia, Montek S. (2005), *Reducing Poverty and Hunger in India: The Role of Agriculture*, International Food Policy Research Institute 2004-2005, Annual Report Essay, Washington, D.C., U.S.A.

Braun, Joachim von; Ashok Gulati, Peter Hazell, Mark W. Rosegrant and Marie Ruel (2005), *Indian Agriculture and Rural Development- Strategic Issues and Reform Options,* International Food Policy Research Institute, Washington, D.C., U.S.A., http://www.ifpri.org/pubs/ib/ib35.pdf.

Creswell, Randy and Franklin W. Martin (1993 and 1998). "Dry land Farming Crops and Techniques for Arid Regions" ECHO, 17391 Durance Rd., North Ft. Myers FL 33917, U.S.A., website-http://www.echonet.org/.

Dhan Foundation (2006), Themes- - Rain fed Farming- -, http://www.dhan.org/rainfed.php.6k.

Gulati, Ashok, Ruth Meinzen-Dick, and K.V. Raju (2005), *Institutional Reforms in Indian Irrigation*, Sage Publications India Pvt. Ltd., New Delhi.

Kumar, Praduman and Surabhi Mittal (2006), "Agricultural Productivity Trends in India: Sustainability Issues", *Agricultural Economics Research Review*, Vol.19, pp. 71-88.

Mittal, Surabhi (2007), Paper prepared for presentation at the Seminar on "US-India Agricultural Knowledge Initiative" organised by ICRIER and Ministry of External Affairs, Government of India on April 30, 2007 held at India Habitat Centre, New Delhi.

Rajakumar, D., K. Sathiya and G. Thiyagarajan (2007), "Constraints in Dry land Agriculture", Science Tech Entrepreneur, Department of Agronomy, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Swaminathan, M.S. (2005), "2006 - - Year of Agricultural Renewal", The Hindu (Daily), December 31.