Risk Management Strategies for Drought-Prone Rice Cultivation: A Case Study of Tamil Nadu, India

K.N. Selvaraj
Tamil Nadu Agricultural University, India
Email: knanjundiahs@gmail.com; nanjundiahselvaraj@hotmail.com

ABSTRACT

This study aimed to understand the issues associated with rainfed rice production in dry and semi-dry areas in Tamil Nadu, India. Farmers face risks such as input, output, market-price, and income, as these areas are prone to rainfall shortage. Secondary data about Tamil Nadu and various water-limited rice environments were studied. A farm survey of 230 farm households in selected districts was conducted in 2001-02 and 2003-04.

Fertilizer use in rainfed areas was reduced due to rainfall shortage. In drought period, crop response to fertilizer declined, causing a decrease in rice yields. Yield variability was higher (44 percent to 60 percent) in drought-prone areas. In rainfed areas, a 10-percent increase in drought risk resulted in a 5.4 percent decline in the yield of modern varieties. In contrast, the effect on landraces was minimal.

Farmers in the rainfed areas are operating at sub-optimal level of production. About 90 percent were inefficient since crop yields were lower than the optimal yield. Farmers incurred an additional cost of Rs 899 to increase yield by 228 kg/ha. An increase in rice productivity by one ton per hectare would replace rice area by 189,208 hectares in Tamil Nadu. Area expansion under rice was noticed in the selected rainfed areas, revealing that infusing high productivity traits in drought-tolerant rice varieties enable farmers to allocate part of their land to other crops.

Traits (genetic and marketability) of widely adopted modern varieties and landraces should be considered in breeding varieties for water-limited environments to earn profits. The results confirm that drought intensity is higher during the maximum-tillering stage, therefore, continued research on development of drought-tolerant rice varieties to withstand early drought is crucial.

Finally, rice income variability in rainfed areas was explained more by variability in yields rather than prices both during normal and risk periods. In other areas, income variability was due to price variability. Yield stabilization would be more effective in keeping revenues stable in rainfed areas, while price stabilization, is an appropriate strategy for reducing revenue risk in irrigated areas.

INTRODUCTION

Understanding and managing agricultural risks in the context of their impact on agricultural production and on people's livelihoods, particularly, in water-limited environments is very crucial. Rainfall is the most critical risk in drought-prone areas. Rainfall risk could be both covariate (a systemic risk) and individual-specific, depending on the onset date of monsoon and rainfall distribution across crops, soil types and regions. Being the most limited production factor in drylands, rainfall has an essential role in determining the cropping pattern.

Price and input risks are higher in water-limited production ecosystems than in irrigated rice ecosystems. There is always a high level of price risk due to substantial lags in agricultural production. Rice is cultivated in a period of four to five months, but decisions are made before output is realized. Farmers' decisions on areas to be allocated for rice in the current seasons depend on previous prevailing market prices (Ramaswami et al. 2003), while losses occur when prices are lower than expected.

Various safety nets are employed by farmers during the stress years (drought years) to cushion adverse impacts. Effectiveness and economic costs of these coping mechanisms vary depending on the intensity of drought and the nature of the production system (Pandey et al. 2000).

Sources of Data

Secondary data for Tamil Nadu and water-limited rice production environments of the selected districts Ramnad, Thiruvallur, and Coimbatore, were collected from published sources. These districts were chosen due to frequent rainfall failure, predominant cultivation of rice under dry and semi-dry conditions, and fast declining water table.[1]

Farm surveys were done in the selected districts. Data were also collected from 230 farm households in 2001-02 and 2003-04. To better understand and address the impact of drought on rainfed rice production, information on the following were gathered: crops cultivated, inputs used, costs incurred, adoption of varieties, and farmers' coping strategies to mitigate the effects of drought.

Description of Selected Districts

Ramnad, Sivagangai and Thiruvallur districts, form 51.58, 11.50 and 10.09 percent, respectively, of the total dry and semi-dry rice areas in the state of Tamil Nadu. Further, of the total rice area in the each district, area under dry and semi-dry rice cultivation constitutes 57.76 percent in Ramnad, 20.37 percent in Sivagangai, and 16.24 percent in Thiruvallur.

A sharp decline in groundwater levels is experienced by many states in India. In some regions – north Gujarat, southern Rajasthan, Saurashtra, Coimbatore and Madurai districts in Tamil Nadu, the Kolar district in Karnataka, the whole of Rayalseema in Andhra Pradesh, and parts of Punjab and Haryana, the decline in water levels due to overexploitation has been as severe as 1-2 meters per year (m/year). Studies have revealed that declining water levels could lead to a 25-percent drop in harvests in the near future.

Over 10 percent of the blocks classified by the Central Ground Water Board have been identified as "overexploited" (exploitation is

[1] Area under rice cultivation was 1.52 million ha in 2002-03. The total irrigated area was 1.375 million ha, accounting for 90.64 percent; the remaining 9.3 percent was under dry and semi-dry conditions.

beyond the critical level), and has been growing at a rate of 5.5 percent every year (World Bank 1999). It is estimated that 36 percent of the blocks in the country will be on the critical list by the year 2017 (www.empowerpoor.org). In Coimbatore district, rice is grown under well and canal irrigation but the water table has been declining at an alarming rate (as per available 1995-2005 data). The rice area under well irrigation is decreasing, particularly, fast.

EMPIRICAL RESULTS

Drought and Agricultural Risks

Rainfall, ground water availability, reservoir levels, and crop conditions determine the nature and extent of drought in Tamil Nadu. The state has four distinct rainfall climates such as the southwest monsoon (June-September), northeast monsoon (October-December), winter (January-February), and summer (March-May). It has eight drought-prone districts covering 833,997 square kilometers, or about 64 percent of the total area of the state. The southern zone is under the rain shadow region, having a prolonged dry climate. Drought occurs frequently in Tamil Nadu and in the sample districts of Ramnad, Thiruvallur, Coimbatore, and Sivagangai. Red, black and alluvial soil types predominate in the state, and sandy soils in the southeastern part are prone to chronic droughts.

About 30 percent of annual rainfall is recorded in the southwest monsoon and 50 percent during the northeast monsoon, mostly from cyclonic activity. The state receives nearly 80 percent of its annual rainfall during the northeast monsoon. On the other hand, it has experienced below normal rainfall in the southwest monsoon for almost a third of the last 25 years (Selvaraj and Ramasamy 2006).

Although the northeast monsoon has a major impact on rainfall distribution and cropping pattern in the state, drought occurs mostly in the southwest monsoon or *kharif* season (June-September), when water demand always exceeds rainfall. Tamil Nadu experienced seven drought years[2] during the last 30 years. Over the same period, Ramnad suffered from drought for six years; Tiruvallur, seven; and Coimbatore, eight. It is evident that droughts occur in the rainfed rice environments of Tamil Nadu once in five years. During the normal period, the average rainfall is 965 millimeters (mm) but during drought, rainfall is 694 mm, representing a 39-percent water shortfall.

The agricultural sector in Tamil Nadu is subjected to erratic monsoon seasons. This is a major factor for high yield risk in rainfed crops, making farmers extremely vulnerable to yield (and income) losses. Seasonwise, rainfall pattern and deficiency during the normal and drought periods are presented in Table 1.

If the rice crop depends solely on rainfall, it needs no less than 30 centimeters per month (cm/month) of rainfall over the entire growing period. Tamil Nadu usually receives only 10 to 20 cm/month of rainfall for four to eight consecutive months (ICAR 2006). In both cropping seasons, high water deficiency was observed in all the drought-prone districts which indicates the prevalence of drought in the said districts. Rice is predominantly grown during the northeast monsoon period in the rainfed areas.

[2] According to the official estimate, rainfall is considered to be in excess if actual rainfall is 20 percent and is more than the normal rainfall. If the deviation between the normal and actual rainfall lies between -19.9 and 19.9 percent, it is classified as normal; if the deviation is between -20 and -59.9 percent, it is considered deficient; and if it is between -60 and -99.99 percent, then it is scanty. For the present analysis, it was classified as a drought year if the deviation between the normal and actual rainfall is -20 percent and above, and normal if the deviation is less than -20 percent.

Tamil Nadu Agricultural University (TNAU) has developed several drought-tolerant rice lines, such as PMK3, PM00 022, PM01 011, PM02 015, PM03 002, Ashoka 200F, Ashoka228, RM96019, IR64 near isogenic line #17, CPMB ACM 04003, and CPMB ACM 04004. Biotechnologists from TNAU developed these varieties to mitigate effects of the late-season drought, particularly during the panicle-initiation stage. However, estimates show that the intensity of drought is higher during the first season and occurs during the maximum tillering stage, emphasizing the need for varieties that can withstand early season drought. Estimates indicating the occurrence of drought against the growth phases of rice cultivation are shown in Table 2.

Input Risk

Although yield increasing technologies have been spreading in dryland areas, farmers often cannot adopt them due to lack of resources, particularly for inputs such as fertilizers[3] and mechanical technologies. Fertilizer use is often considered to be a function of the level of irrigation, use of high-yielding varieties (HYVs), cropping pattern, prices of crops, and cost of fertilizers. A strong association between expenses on irrigation and use of fertilizer in irrigated crops was observed by many studies, while lack of capital and uncertainty about soil moisture conditions are factors restricting fertilizer use in crops in the low rainfall regions. Average annual use of nitrogen (N), phosporus (P) and potassium (K) per hectare in Tamil Nadu (gross cropped area) for the period between 1985-86 and 1998-99 was 87.90 kilograms (kg), 32.15 kg and 34.78 kg respectively in irrigated areas, while it was 54.62 kg, 20.08 kg, and 25.72 kg in rainfed areas.

Since HYVs require more fertilizers to realize their yield potential, fertilizer application was higher in irrigated areas although there was a decline in their use over the period between 1985-86 and 1998-99 (Selvaraj et al. 2002). Fertilizer use in rainfed areas is still less than half the rate used in irrigated areas. Evidences show that fertilizer application in consonance with the onset of the monsoon and soil moisture availability results in a minimum of 50 percent increase in yield with benefit cost ratio of 3:1. Low, and most often, improper matching of soil moisture and fertilizer application in rainfed agriculture have reduced farmers' chances of achieving higher crop yields.

The strategy for future growth in fertilizer use rests on exploiting the remaining untapped potential (mostly in dryland areas) and raising the economic benefits of fertilizer use through improved fertilizer response. The risk due to drought is reflected in the level of investment made in modern inputs such as fertilizers and pesticides. In 2006-07, the average level of fertilizer application in the state was 51.36 kg (N), 20.71 kg (P), and 24.76 kg (K) per hectare. Further, it was noticed that there was a marginal decline in per hectare fertilizer use in the state and all the water limiting production environments during the drought period. Nitrogenous fertilizer use in the state decreased from 0.468 million tons during the normal period to 0.409 million tons during the drought period; there was a similar reduction in the use of phosphate and potash fertilizers (Tables 3 and 4). Fertilizer application for rice was less in the drought period, particularly in Ramnad. The reduction was very high compared to the other production environments since non-system tank, which depends on rainfall, forms the major source of irrigation[4] in this district (Table 5).

[3] Average use of fertilizer per ha in rainfed areas is only 25 kg in India and it is more predominantly used in irrigated areas and for high value cereals like rice and wheat.

Table 1. Rainfall deficiency and extent of drought during the two rice cropping seasons (mm)

Period	Rice cropping season I (Kar/Kuruvai/Sornavari)*			Rice cropping season II (Samba/Thaladi/Pisanam)*		
Coimbatore	**April-July**	**May-Aug**	**June-Sep**	**Aug-Dec**	**Sep-Jan**	**Oct-Feb**
Normal	192.67	178.59	198.99	349.85	321.65	241.18
Drought	158.12	156.47	159.66	211.31	179.36	117.94
Deficit	34.55	22.12	39.33	138.54	142.29	123.24
Ramnad	**Sep-Dec**	**Oct-Jan**	**Nov-Feb**	**Jan-Apr**	**Feb-May**	**Mar-June**
Normal	600.03	556.36	384.11	112.58	126.15	125.34
Drought	361.58	297.74	174.60	69.88	113.54	121.04
Deficit	238.45	258.62	209.51	42.70	12.61	4.30
Thiruvallur	**June-Sep**	**July-Sep, Dec**	**Aug-Sep, Dec-Jan**	**Sep, Dec-Jan**	**Dec-Mar**	**Jan-Apr**	**Feb-June**
Normal	461.22	550.11	469.14	343.55	201.52	52.71	74.95
Drought	395.33	395.85	309.88	182.4	77.76	34.98	56.55
Deficit	65.89	154.26	159.26	161.15	123.76	17.73	18.40
Tamil Nadu	**June-Sep**	**July-Oct**	**Aug-Nov**	**Oct-Jan**	**Nov-Feb**	**Dec-Mar**
Normal	315.87	451.31	591.37	505.43	339.75	150.92
Drought	292.93	390.8	447.82	290.27	161.42	66.55
Deficit	22.94	60.51	143.55	215.16	178.33	84.37

* Local terms for the cropping seasons which vary among the different areas

Source: Estimated using secondary data collected from various issues of Season and Crop Report, Tamil Nadu

Table 2. Occurrence of drought vis-à-vis the growth stages of rice (mm)

Days	Water requirement	Drought period rainfall *		Deficit	
		Season I	Season II	Season I	Season II
First 30 days	507.89	33.75	117.95	504.14	389.94
Second 30 days	246.68	57.15	131.62	189.53	115.06
Third 30 days	145.28	84.08	114.17	61.20	31.11

* Average of drought months in Ramnad District

Source: Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore-3 and Secondary data from published

Although the t-test results were unable to prove a significant reduction in fertilizer use during the drought periods, the reduction was alarming based on the rate of growth of fertilizer consumption (Table 3, 4, and 5). The mean fertilizer use was estimated from the normal periods of three years in the 1970s, four years in the 1980s, five years in the 1990s, and five years in the 2000s[5], while the drought periods comprise six years in the 1980s, five years in the 1990s and two years in the 2000s. In Tamil Nadu and the selected districts, fertilizer consumption in the early years was low but increased in the later years based on the estimated growth rates.

Ramnad is a dry district where non-system tank[6] is the major source of irrigation, hence, rainfall pattern is the most decisive factor. In Coimbatore and Thiruvallur, wells are the major source of irrigation and the effect of rainfall failure is lower compared to Ramnad.

Reduction in total fertilizer use was not statistically significant in Ramnad, but reduction in per hectare consumption was statistically significant at high levels of probability. Moreover, N use declined by 94 percent and P and K by 50 percent each (Table 4). Reduction in per hectare use and consumption by the rice crop was also higher.

Estimates of variability in fertilizer use prove that farmers in fragile environments are reluctant to apply the recommend doses of fertilizers (Table 6). This is particularly true in Ramnad where the drought is more severe and the estimated variations are higher (compared to the other districts), during both the normal and drought periods. Overall data for Tamil Nadu shows a decrease in fertilizer use during the drought periods. Differences in the decline in fertilizer use were also observed among the districts due to various factors.

[4] Tank irrigation, which was the major source of irrigation during the fifties and sixties, has lost its share despite the increase in number mainly because of encroachments and silting in the feeding channels. Area irrigated by tanks decreased due to the combined effect of low rainfall and decreased holding capacity of the tanks. The net area irrigated by tanks which was 912,000 ha during the sixties (36.8 percent of the total net area irrigated) dropped to 424,000 ha by 2002-03. Tank-irrigated areas in 2002-03 is the highest in Kancheepuram district (15 percent), followed by Sivagangai (14.9 percent), with the following figures for some other districts: Pudukkottai, 13.1 percent; Ramanathapuram, 13 percent; Thirunelveli, 8.9 percent; and Virudhunagar, 6.9 percent.

[5] Data for 30 years from 1977-78 to 2006-07 were collected to determine drought and normal years based on methodology as described. 1970s data were from 1977-78, 1978-79, and 1979-80 only; rainfall was normal for these three years. Ten years of data were included each for the 1980s and 1990s, and 7 years for the 2000s (2000-01 to 2006-07).

[6] Two types of tank irrigation systems exist. One is system tank which depends on river flow and rainfall; another is non-system tank which depends solely on rainfall.

Table 3. Effect of drought on nutrient use (million tons)

	Normal period			Drought period			t-value			2003-04		
	N	P	K	N	P	K	N	P	K	N	P	K
Coimbatore	0.030	0.016	0.018	0.029 (-3.33)	0.024 (50.00)	0.013 (-27.78)	0.94	-0.62	**2.03****	0.072 (1.09)	0.028 (-5.69)	0.042 (4.51)
Ramnad	0.009	0.002	0.002	0.006 (-93.75)	0.001 (-50.00)	0.001 (-50.00)	0.25	0.19	0.30	0.025 (2.77)	0.007 (4.06)	0.009 (6.10)
Thiruvallur	0.037	0.014	0.013	0.032 (-13.51)	0.013 (-7.14)	0.012 (-7.69)	0.09	0.05	0.01	0.045 (0.91)	0.017 (0.13)	0.016 (-1.11)
Tamil Nadu	0.468	0.174	0.212	0.409 (-12.61)	0.151 (-13.22)	0.197 (-7.08)	**3.44*****	**2.19****	0.61	0.558 (2.12)	0.225 (2.13)	0.269 (2.43)

***significant at 0.01 level; **significant at 0.05 level
Figures in parentheses under the "Drought period" column denote percentage decline from the normal period.
Figures in parentheses under the "2003-04" column denote estimated compound growth rates for the period between 1990-91 and 2003-04.

Source: Various issues of Season and Crop Report of Tamil Nadu, Department of Economics and Statistics, Tamil Nadu.

Table 4. Effect of drought on per hectare fertilizer use (kg)

	Normal period			Drought period			t-value			2003-04		
	N	P	K	N	P	K	N	P	K	N	P	K
Coimbatore	80.70	37.93	43.07	80.26 (-0.55)	48.24 (27.18)	36.31 (-15.70)	0.09	-0.88	1.19	100.77 (0.17)	39.19 (-0.22)	58.78 (0.22)
Ramnad	49.08	13.12	15.24	30.12 (-38.63)	6.38 (-51.37)	5.41 (-64.15)	**2.65****	**2.49****	**3.35*****	54.18 (0.20)	15.17 (0.06)	19.51 (0.08)
Thiruvallur	96.70	37.16	33.29	112.53 (16.37)	43.96 (18.30)	42.90 (28.84)	1.38	0.99	1.39	117.57 (-0.12)	44.42 (-0.07)	41.80 (-0.10)
Tamil Nadu	66.20	24.57	29.97	61.93 (-6.45)	22.81 (-7.16)	29.80 (-0.56)	1.48	1.14	0.05	85.59 (0.11)	34.51 (0.04)	41.26 (0.06)

***significant at 0.01 level; **significant at 0.05 level

Figures in parentheses under the “Drought period” column denote percentage decline from the normal period.

Figures in parentheses under the “2003-04” column denote estimated compound growth rates for the period between 1990-91 and 2003-04.

Source: Various issues of Season and Crop Report of Tamil Nadu, Department of Economics and Statistics, Tamil Nadu

Table 5. Effect of drought on per hectare nutrient use in rice production (kg)

	Normal period			Drought period			t-value			2003-04		
	N	P	K	N	P	K	N	P	K	N	P	K
Coimbatore	48.42	22.76	25.84	48.16 (-0.54)	28.95 (27.20)	21.78 (-15.71)	0.09	-0.88	1.192	60.46 (1.97)	23.51 (-4.87)	35.27 (5.42)
Ramnad	29.45	7.87	9.15	18.07 (-38.64)	3.83 (-51.33)	3.24 (-64.59)	0.09	0.07	0.10	32.51 (4.03)	9.10 (5.33)	11.70 (7.41)
Thiruvallur	58.02	22.30	19.98	67.52 (16.37)	26.37 (18.25)	25.74 (28.83)	-0.04	-0.03	-0.04	70.54 (-1.11)	26.65 (-1.87)	25.08 (-3.10)
Tamil Nadu	39.72	14.74	17.98	37.16 (-6.44)	13.69 (-7.12)	17.88 (-0.56)	1.48	1.14	0.05	51.36 (1.55)	20.71 (1.57)	24.76 (1.86)

Figures in parentheses under the “Drought period” column denote percentage decline from the normal period.
Figures in parentheses under the “2003-04” column denote estimated compound growth rates for the period between 1990-91 and 2003-04.
Source: Secondary data collected from various issues of Season and Crop Report of Tamil Nadu, Department of Economics and Statistics, Tamil Nadu

In Tamil Nadu, rainfall is the most crucial factor for adoption of modern technological inputs, specifically, inorganic fertilizers. Many studies proved that crop response to fertilizer is higher in irrigated areas as reflected in the strong correlation between irrigation water and fertilizers. With the exception of rainfall, it is evident from the rice yield that the elasticity of response to fertilizer inputs declined during the drought period. Production elasticity of factor inputs is not significant and turned out to be negative in the case of phosphorus, as shown in Table 7.

Fertilizer response estimates are positive and significant in determining rice productivity during the normal period, as response to fertilizer inputs is higher with adequate irrigation and soil moistures. Response coefficient of fertilizers, however, is found negatively significant and highly elastic, implying that productivity response to nitrogen is declining. Such relationship is expected because fertilizer use (particularly nitrogen) in Tamil Nadu and in many of the other states in the country has increased very sharply due to fertilizer subsidies and farmers' practice. Farmers tend to apply more nitrogen fertilizer than the recommended rates with the hope of getting higher yields. However, productivity has not increased proportionately with the increase in the fertilizers applied; rather, the marginal productivity of rice declined over the period (Table 8).

In 1985-86, farmers in India applied 0.05 kg of NPK fertilizer to produce 1 kg of food grains; today they are applying double that quantity, or 0.10 kg of fertilizer to produce the same amount of yield. The parity between rice and fertilizer (N) was 0.50 in 1995-96, and 0.53 for wheat during the same period. Although the ratio has not deteriorated much by 2005-06 (0.54 for rice and 0.62 for wheat) due to the almost parallel increases in the prices of the produce and fertilizers, there is inefficiency in fertilizer use. Increase in fertilizer prices and decline in their marginal productivity (fertilizer-use efficiency or FUE) increased cost of production.

Yield Risk

In 2006-07, the state's rice area was 1.52 million hectares planted with the following varieties: ADT43 (nearly 21%), Improved White Ponni (16%), ADT39 (14%), ADT36 (8%), CO43 (7.5%), ADT38 (6.73%) and IR20 (6%). Displacement of traditional varieties by improved varieties has changed production practices especially in terms of increased use of fertilizers and pesticides. Impact of improved varieties on production risks has been controversial. The issue is the relative susceptibility of improved varieties to moisture stress and pests compared to the traditional ones. Improved varieties do well in assured rainfed or irrigated environments. As they are more fertilizer responsive under optimum conditions, improved varieties have better vegetative growth – which is widely believed to encourage more pest attacks.

Empirical evidences show that over time, the area under HYVs[7] has increased in both irrigated and dryland areas. However, there is a big yield gap between irrigated and dryland or rainfed areas. Although use of HYVs has spread to dryland areas, adoption of associated technologies has been poor (Asaduzzaman 1979; Shotelersuk-vivat 1981; Agarwal 1983; Thapa 1989; Fugile 1992; Hossain 1990;

[7] About 40 percent of the cropped area in the country was planted with HYVs by 2002-03 which increased from 21 percent in 1970. Area under HYVs of crops ranged between 2 percent to 69 percent across the states with 0.60 Gini coefficient, implying that there is wide variation (Ramasamy and Selvaraj 2001), due to differing levels of technology adoption and associated factors apart from rainfall variability.

Table 6. Variability in fertilizer use during the normal and drought periods (Coefficient of variation in percent)

District	Total fertilizer consumption								Per hectare consumption							
	Normal Period				Drought Period				Normal Period				Drought Period			
	N	P	K	NPK	N	P	K	NPK	N	P	K	NPK	N	P	K	NPK
Ramnad	54.43	46.97	77.85	52.13	55.49	41.99	62.10	42.48	35.61	47.57	12.98	58.49	75.09	90.91	29.46	75.14
Coimbatore	19.13	23.26	27.83	17.98	14.44	16.77	29.12	17.43	36.14	39.99	24.97	28.90	9.91	19.12	20.63	15.58
Thiruvallur	51.46	47.84	36.38	47.11	2.47	6.06	23.47	4.16	33.04	38.79	36.31	34.00	43.45	47.29	48.36	15.90
Tamil Nadu	20.33	32.51	34.48	25.62	20.20	25.27	28.04	22.13	29.18	42.46	39.09	68.90	12.58	17.19	18.38	20.81

Data presented cover 2004-05, 2005-06, and 2006-07

Table 7. Effect of drought on rice yield response to inputs # - log linear estimates

	Normal	Drought
	Auto correlation adjusted coefficients	Auto correlation adjusted coefficients
Constant	-0.107	-3.337
	(-0.060)	(-0.331)
N (kg/ha)	-1.162***	0.256
	(-4.768)	(1.417)
P (kg/ha)	0.738***	-0.127
	(5.827)	(-0.924)
K (kg/ha)	0.351**	0.111
	(2.291)	(0.948)
Rainfall (mm)	0.253	0.308**
	(1.002)	(2.219)
Trend (time)	0.030*	-0.00001
	(1.618)	(-0.002)

Districts constitute the sample
Dependent variable: Productivity (kg/ha)
***significant at 0.01 level; **significant at 0.05 level ; *significant at 0.10 level

Source: Estimates were calculated based on the secondary data collected from various issues of Season and Crop Report of Tamil Nadu, Department of Economics and Statistics, Tamil Nadu

Table 8. Effect of nitrogen consumption on yield

Normal period				Drought period			
Year	N/ha (kg/ha)	Rice yield (kg/ha)	*Ratio*	*Year*	N/ha (kg/ha)	Rice yield (kg/ha)	*Ratio*
1977-78	36.70	2050	0.1697	1980 -81	104.83	1861	0.0563
1978-79	42.30	2017	0.0234	1982-83	95.41	1845	0.0517
1979-80	41.80	1996	0.4811	1984-85	97.31	2138	0.0455
1980 -81	104.83	1865	0.1876	1986-87	93.26	2728	0.0342
1983-84	98.64	1898	9.4936	1988-89	101.85	3032	0.0336
1985-86	103.85	2372	1.7149	1989-90	111.79	3089	0.0362
1987-88	103.14	2786	0.3216	1990-91	64.75	3116	0.0208
1993-94	57.80	2927	0.0152	1991-92	70.36	3115	0.0226
1994-95	64.88	3394	0.0139	1992-93	64.43	3116	0.0207
1996-97	74.92	2671	0.0095	1995-96	66.69	2558	0.0261
1997-98	78.52	3050	0.0015	1999-00	85.15	3481	0.0245
1998-99	79.08	3579	1.6544	2000-01	82.54	3541	0.0233
2002-03	64.19	3588	0.0062	2001-02	77.46	3196	0.0242
2003-04	60.08	2926	0.1957				
2004-05	77.50	3015	0.1522				
2005-06	95.00	2900					
2006-07	99.50						
Correlation			**0.02573**				**0.39704**

Hossain 1996). Nevertheless, the performance of Tamil Nadu's agricultural sector has been impressive since the 1960s when early modern crop varieties were introduced[8].

With the introduction of modern varieties, a phenomenal breakthrough in productivity of crops was achieved, resulting to higher yields for most crops. Although HYVs have brought huge gains in yield, yield variability was still a production risk as evident from the yield gaps and yield variability among the rice varieties in irrigated and rainfed environments during the normal and drought periods (Tables 9 and 10).

Although yield gap was reduced over time in both irrigated and rainfed ecosystems, the rate of reduction was higher in the irrigated environment due to favorable technologies and available resources. The estimated yield gap, which was 1,653 kg/ha during 1970s in the irrigated areas, declined to 152 kg/ha by the 1990s. In water-limited environments, it was reduced from 943 kg/ha to 443 kg/ha during the same periods. Moreover, yield variability of HYVs was also higher during the drought period compared to the landraces (Table 10).

[8] Rice yield recorded a compound growth rate of 2.13 percent from 1965 to 2002 in Tamil Nadu, with a specially high growth rate of 4.69 percent during the 1980s. However, productivity of rice registered a negative growth rate of 0.38 percent in the1990s. Growth rate of rice in terms of area, production, and productivity varied among the various production environments such as rainfed tank, tank, tank-cum-well, canal (river), and canal (reservoir). Productivity growth in rainfed tank environment (including the large tract of dryland regions with less dependable water resources) was quite stagnant from 1984 to 2002, with rice yields recording only 0.12 percent growth (compound growth rate for the whole period).

According to the National Commission of Agriculture, rainfall fluctuations could be responsible for 50 percent of variability in yields. Estimates in Table 11 show that yield variability was found higher compared to area variability in the rainfed environment even during the normal period. As farmers usually have no options except to cultivate rice even during the drought period, area variability was found to be less. Yield variability increased during the drought period due to risk of rainfall failure. Area variability, on the other hand, was lowest in Coimbatore district during the normal period, while yield variability was found highest in Ramnad district during the drought period.

Wells are the major source of irrigation in Thiruvallur district. During drought periods, the wells dry up, resulting in productivity losses. Wells (45 percent) and tanks (40 percent) are the major sources of irrigation in Thiruvallur; rainfall failure affects the area under rice cultivation as evident in the high area variability during droughts in this district. Decline in rainfall in Ramnad was more than 50 percent during the drought period, which explains why the district has the highest yield variability.

Irrigation tanks, also a major source of irrigation in the rainfed areas, do not have sufficient water even during the normal period. They also usually dry up during the drought

Table 9. Rice productivity in irrigated and water limiting environment (kg/ha)

	Irrigated			Rainfed		
	Potential*	Actual	Gap	Potential**	Actual	Gap
1970s	3700	2047	1653	2180	1237	943
1980s	3700	2678	1022	2180	1653	527
1990s	3700	3548	152	2180	1737	443

Table 10. Yield variability of rice varieties (CV percent)

	Normal period	Drought period
HYVs		
ADT-36	8.70	17.38
IR-20	17.28	28.93
ADT-39	9.44	18.00
ADT-43	22.98	26.89
J-13	7.78	13.81
Bapatla	10.84	19.82
TKM-9	3.68	12.65
White Ponni	4.41	11.85
Landraces		
Chittiraikar	8.97	8.92
Norungan	5.61	5.57

Source: Farm survey

period, resulting in crop failure. Farmers broadcast the seeds immediately after the first shower, expecting subsequent rainfall during the cropping period. If rainfall fails, the entire crop is lost. Thus, planting of landraces such as *Chitraikar, Norungan* and *Nootripattu* during drough period in the Ramnad district was found higher, as these are more water-stress tolerant and assure a minimum yield. Yield variation among the non-drought and drought-prone districts also show that yield variability was found highest in Ramnad (44 to 60 percent), despite the fact that the other districts also experienced higher variability during the drought period (Table 12).

Farmers in rainfed production environment are operating at sub-optimal level. Optimal cost of cultivation and optimum yield for rainfed and rainfed with supplementary sources of irrigation were estimated using the transcendental production function:

where:
X_{i^*} = Optimal cost of cultivation
y^* = Optimum yield

$$Y = a_0 x_1^{a1} x_2^{a2} e^{b1x1 + b2x2}$$
$$\ln Y = \ln a_0 + \sum a_i \ln x_i + \sum b_i x_i$$

Further, comparison of actual and optimal cost of cultivation reveals that for the production level realized by the farmers, they incurred higher cost due to drought risk and adoption of varieties with less response to technological inputs (such as fertilizers). Under the rainfed condition, farmers incurred an additional cost of Rs 899 to realize their (actual) yield; opportunity exists to increase yield by 228 kg per hectare with the available technology and resources. About 90 percent of the farmers (or farms) in the rainfed environment are found inefficient since their actual yields were lower than the optimal yields (Table 13).

Econometric results indicate that yield loss due to risk of rainfall failure was higher in HYVs compared to landraces. A 10-percent increase in risk resulted in 5.4-percent decline in yield of modern varieties in Ramnad district. However, yield reduction in landraces was minimal; a 10-percent increase in risk caused a yield decline of only 0.2 percent (Table 14). However, yield reductions of HYVs in the districts of Sivagangai and Thiruvallur were found to be less despite the variability in rainfall due to supplementary

Table 11. Decomposition of instability in annual output growth rate of rice during the normal and drought periods

District	Percentage of variation in output growth rates (1970-71 to 2002-03)								
	Normal period			Drought period			Overall		
	Area	Yield	Cov (A,Y)	Area	Yield	Cov (A,Y)	Area	Yield	Cov (A,Y)
Coimbatore	10.45	86.25	3.30	22.25	65.34	12.41	78.01	15.44	6.55
Ramnad	12.15	72.81	15.04	5.57	70.85	23.58	14.07	70.57	15.36
Thiruvallur	21.41	77.61	0.98	91.44	5.65	2.91	27.66	62.01	10.33
Tamil Nadu	34.19	56.22	9.59	19.73	76.7	3.55	34.00	54.16	11.84

Cov - Covariance; A - Area; Y - Yield

Table 12. Rice productivity variation in non-drought prone and drought-prone districts of Tamil Nadu

District	Productivity during the normal period (kg/ha)			Productivity during the drought period (kg/ha)			CV (%)	
	Max	Min	Mean	Max	Min	Mean	Normal period	Drought period
Non-drought prone districts								
Chengalpattu	3383	1685	2629	3206	1517	2409	23.98	29.02
Kancheepuram	3486	3021	3205	3544	2562	3114	6.81	9.27
Pudukottai	3158	1612	2329	3587	829	2420	24.51	30.19
Thanjavur	3182	1581	2438	3748	2062	2823	19.68	18.08
Thiruvarur	2999	1395	2111	3795	856	2428	38.34	46.96
Nagapattinam	3346	864	1980	3660	1158	2753	41.87	37.18
Madurai	4699	2329	3356	4434	1806	3092	19.69	24.44
Average							**24.98**	**27.88**
Drought prone districts								
Ramnad	3322	164	1662	1939	102	894	43.53	59.70
Sivagangai	3082	652	766	2600	804	504	36.06	28.02
Thiruvallur	3921	2609	3233	3908	2800	3358	17.40	14.14
Coimbatore	3880	2229	3169	4045	2307	3306	18.09	14.30
Average							**28.77**	**29.04**
Tamil Nadu	**3579**	**1674**	**2582**	**3541**	**1845**	**2844**	**21.25**	**19.85**

sources of irrigation[9]. Yield reduction of HYVs would have been 2.0 percent in Sivagangai and 0.6 percent in Thiruvallur if risk of drought were to increase by 10 percent.

Farmers in Ramnad district attained 4.2 tons/ha of yield from the HYVs during the normal period, and 3.3 tons/ha from the landraces. Although the yield of local varieties was lesser even during the normal period, farmers cultivate them due to assurance of minimum levels of yield during droughts. Farmers realized an incremental benefit of Rs. 5,783/ha by cultivating landraces during the drought period compared to normal times, while cultivation of HYVs during the normal period fetches an incremental benefit of Rs. 2,165[10]/ha over landraces (Table 15).

[9] Wells constitute the primary source of irrigation in Tamil Nadu, accounting for about 54.7 percent of the net area irrigated in 2002-2003. Both the number and area irrigated by wells registered significant increase over the years. Number of wells (dug and tube wells) increased from 1.683 million in 1980-81 to 1.844 million in 2002-03; the area irrigated by wells rose from 1.038 million ha to 1.453 million ha during the same period. Net area irrigated by wells registered a three-fold increase during the last five decades; as a result, there is over exploitation of ground water in the state. Net area irrigated by wells in 2002-03 was the highest in Coimbatore district, with 9.7 percent of the total net area irrigated by wells in the state.

Table 13. Efficiency of rice production

	Cost of cultivation (Rs/ha)		Yield (kg/ha)	
	Actual	**Optimum**	**Actual**	**Optimum**
Rainfed with supplementary sources	14471	14775	4416	4416
Rainfed	7433	6535	2498	2726

Source: Household survey

Table 14. Impact of risk (drought) on yield of rice - log linear estimates

	Coefficients	t-value
Ramnad		
HYVs	-0.540**	-2.746
Landraces	-0.016	-0.110
Sivagangai		
HYVs	-0.190*	-1.736
Thiruvallur		
HYVs	-0.062**	-2.442

***significant at 0.01 level; **significant at 0.05 level

Source: Farm survey

Therefore, varieties meant for water-limited environments should ensure minimum levels of yield during the stress periods and induce farmers to go for higher levels of adoption. Breeding rice varieties which ensure minimum yield levels for higher revenues assumes paramount importance as yield reductions of HYVs are higher during stress periods. Drought-tolerant rice varieties, through Marker-Assisted Techniques, were developed for better adaptability to stress conditions and farmers have started cultivating these rice varieties. However, expansion of area under such varieties depends on seed availability and market acceptance.

Technological change in rice cultivation requires higher input use in terms of fertilizers, pesticides, and labor (Table 16). Factor shares under different technologies (modern varieties and landraces) were estimated using the Hicks Formula:

$$R_i = a_i +/n\sum a_i$$

where:

R_i = Relative Factor Production Elasticity of ith factor

a_i = output elasticity of the ith factor

$$Z_i = \frac{(R_i)_{NT} - (R_i)_{OT}}{(R_i)_{OT}} \gtreqless 0$$

Factor-i using/share of i-th factor increases

Factor-i neutral/share of i-th factor remains constant

Factor-i saving/share of *i*-th factor decreases

Z_i is a measure of the proportionate rate of change in factor share of i-th input with technical

[10] Rs 45.88= 1USD

Table 15. Performance of HYVs and landraces during drought period (Rs/ha).

	Landraces		HYVs	
	Added cost/ Reduced return	Reduced cost/ Added return	Added cost/ Reduced return	Reduced cost/ Added return
Cost	-	2563	2563	-
Return	-	3220*	-	4727
Total	-	5783	2563	4727
Incremental benefit (Rs)		5783		2165

* Based on the difference in the yield reduction of HYVs and landraces due to drought. Although yield reduction is lower in landraces, productivity of HYVs is nevertheless still higher during the drought period. However, due to reduction in cost, landraces fetch marginally higher returns.

Source: Farm survey

change; $(R_i)_{NT}$ is relative factor production elasticity of i-th input under new technology (adoption of modern varieties); and $(R_i)_{OT}$ is relative factor production elasticity of i-th input under old technology (use of landraces).

Due to their nutrient responsiveness, HYVs warrant higher rates of fertilizer application. Application of more fertilizers, however, induces weeds to grow easily and profusely, requiring more labor for weeding. Further, labor requirement for other operations like planting, harvesting, and threshing is higher in the case of HYVs compared to landraces. Use of synthetic pesticides is also higher with HYVs while landraces are much more resistant to pests and diseases.

The production elasticity of fertilizer (0.319) and labor (1.051) implies that marginal returns from application of fertilizers and labor are higher in HYVs compared to landraces. Use of higher doses of fertilizers in the cultivation of landraces affects the standing crop. As farmers in rainfed areas normally apply lesser amounts of fertilizers (even for HYVs) due to drought risk, they are unable to reach their expected yields. Therefore varietal development for rainfed areas should assure a minimum level of yield in order for farmers to earn some profit, particularly in the event of rainfall failures.

Results of decomposition analysis reveals that reduction in yield due to cuts on inputs, is 9 percent, and more than 30 percent of yield reduction is due to water stress (Table 17). Decomposition analysis was specified as follows:

$$\ln Y_D = \ln A_D + B_D \ln L_D + C_D \ln F_D + D_D \ln P_D + \mu_D \qquad (1)$$

$$\ln Y_N = \ln A_N + B_N \ln L_N + C_N \ln F_N + D_N \ln P_N + \mu_N \qquad (2)$$

where, D refers to rice yield during drought period and N denotes rice yield during normal period. Y pertains to yield (kg/ha); L is labor use (labor days/ha); F is fertilizer consumption (kg/ha) and P stands for pesticides and fungicides (Rs/ha).

Taking the difference between (1) and (2), adding some terms and subtracting the same terms yield the following:

$$\ln(Y_D/Y_N) = \ln(A_D/A_N) + [(B_D - B_N)\ln L_N + (C_D - C_N)\ln F_N + (D_D - D_D) \ln P_N] + [B_D \ln(L_D/L_N) + C_D \ln (F_D/F_N) + D_D \ln(P_D/P_N)] \qquad (3)$$

Table 16. Estimates of factor share under different technologies and proportionate change in the estimated factor shares

Factor inputs	Factor share		Proportionate change
	Landraces	HYVs	
Land	1.498	0.367	-0.755
Fertilizer	0.096	0.284	1.958
Labor	-0.172	0.259	-2.506
Pesticides	-0.422	0.090	1.213

Source: Farm survey

Equation 3 involves decomposing the natural logarithm of the ratio of rice productivity during drought and normal periods.

Estimates by Ramasamy et al. (2003) show that rice production loss due to drought can be as high as 30 percent of the state total rice production, valued at Rs. 8.521 billion, which accounts for 5.54 percent of the state's GDP. Loss in employment was 17 percent, which was calculated based on the employment elasticity of 0.6 (Bhalla 1987). For rice, the average labor requirement per hectare is 159 labor days, but incidence of drought resulted in loss of employment by around 28 labor days per hectare; at the state level, it works out to 60 million labor days. To compensate for this loss, Rs. 3 billion is needed as additional investment to generate employment.

Price Risk

Price support has been the principal means by which Indian farmers have received some protection against market risks. The support prices for some of the crops have been consistently fixed higher than the counter-factual market price, which may tend to increase stocks. If the stocks are not sustained, then farmers face a policy risk depending on how the stocks are reduced. Aside from other factors, the government support price mechanism played a crucial role in minimizing the market aberrations caused by natural calamities. The government maintains an adequate stock of food grains during the short supply periods, thereby, any market eventualities due to production shortfalls can be properly managed. Data for 2006-07 shows that the country's stock of food grains was about 25 million tons and over the years, such buffer stock has been maintained to cope with any market abnormalities. However, there is an apprehension about maintaining such huge stocks since it also leads to huge inventory and carry-over costs.

There are also private mechanisms that can potentially help farmers cope with private risks. Some crops are characterized by substantial market risks and contracting allows the transfer of these risks from the farmer to the traders or processors. For specialty crops and vegetables, contract farming is gaining ground as a mechanism by which private processors obtain supplies directly from farmers. This system appeals to growers because of the price insurance that it offers. Accumulated evidences prove that price stability is a major benefit of contract farming for farmers.

However in water-limited rice production environments, yield-boosting technologies are construed as instruments that promote risk-taking among farmers in the absence of a private mechanism like contract growing. Because

Table 17. Decomposition of rice production in rainfed environment (percent)

Source of change	Coimbatore	Ramnad	Sivagangai	Thiruvallur
Change in output	-21.31	-38.26	-32.37	-9.18
Drought	-14.01	-29.71	-25.25	-4.26
Change in input	-7.3	-8.55	-7.12	-4.92
Labor	1.24	1.82	1.96	0.36
Fertilizer	-6.14	-9.73	-8.17	-5.45
Pesticides	-2.19	-0.97	-0.82	1.13

Source: Household survey

the farmers predominantly cultivate rice in these environments and they cannot transfer production risk to someone else through contract growing (as the system is not practiced in rice production), purchasing insurances may be an option since no private parties offer protection against idiosyncratic risk.

Price risk also depends on the extent of exposure to market forces and existing market institutions. Although production risks have consequences for price risks, the latter is not just because of production risks alone. Prices can vary also because of demand shocks and instability in expectations formation. As the demand for staples is largely inelastic, supply shocks are magnified due to price variations. The results shown in Table 18 reveal that due to inelastic demand for agricultural commodities particularly for rice, even a small change in supply causes high price shock.

Aside from production risks, supply shifts are also caused by variability in planned supply, i.e., area planted to a particular crop. Although rice production in the state declined by 1 million tons due to drought, real wholesale price has not increased but declined due to public price stabilization measures (Table 19). However, in spite of the decline in absolute real prices, the change in price was higher during the drought period compared to the normal period.

Month-wise, price changes were also higher during drought periods compared to the normal years. As a result, farmers are subjected to more price fluctuations caused by drought (Table 20). Table 21 confirms this high price variability, estimates of instability index of real retail prices of rice were higher during the drought period.

Income Risk

Technological change, widespread adoption of modern varieties, and improved infrastructure (especially irrigation) are the important factors that contributed significantly to achieve rapid growth in the agriculture sector, particularly rice production over the past 35 years. As a result, there has been a decline in poverty levels (Hazell and Ramasamy 1991; Pingali et al. 1997; Pingali and Hossain 1999; Bhatia 1999; Janaiah et al. 2000; and Hossain 2001).

However, the disadvantaged regions have not enjoyed the benefits of agricultural and economic growth. Studies have found that the incidence, depth, and severity of poverty were lower in the more technologically developed regions , such as those with irrigated ecosystems. Dryland technologies are also still inadequate to get small and marginal farmers out of the poverty trap in dryland regions. Further, deceleration in the growth rate of food grains production

Table 18. Impact of supply shock on rice prices

District	Normal period			Drought period		
	CV (P)	CV (Y)	SS_P	CV (P)	CV (Y)	SS_P
Coimbatore	69.01	19.01	47.54	42.09	21.27	53.18
Ramnad	62.73	40.46	101.15	41.90	47.95	119.87
Thiruvallur	61.66	35.78	89.32	99.41	24.97	62.43
Tamil Nadu	57.35	33.99	84.97	52.73	37.73	94.33

Demand Elasticity is 0.4 (Krishnamoorthy and Selvaraj 1996)
CV (P) = CV(Y) / E_D
CV (P) – Coefficient of variation in price
CV(Y) – Coefficient of variation in yield
E_D - Elasticity of demand
SS_P - Supply Shock on price

Source: Secondary data

(especially that of rice) due to high climatic risk, coupled with growing income inequality due to high variability in production during the drought period stalled poverty in these fragile environments. Since rural poverty is positively correlated with relative food prices, which are affected by fluctuations in food supply, poverty remains high in the more marginalized regions.

The negative correlation between prices and yields reduces crop revenue fluctuations and may provide a natural hedge to farmers, but such relationship was not observed in most of the rice production environments (Table 22). Fluctuations in rice income were due to variations in price during the normal and drought periods, except in Ramnad where income variation was due to yield variation.

It is imperative to maximize the risk-taking ability of farmers. Several studies propose alternative solutions in this regard such as reducing input prices and raising the output prices. However, fixing higher prices for outputs may lead to the possibility of the large farmers getting an extraordinary level of profit and a further perpetuation of income inequalities. This suggests that “perfect” price stabilization could destabilize incomes in some districts which can happen if the yield component is greater than the sum of price component and the price-yield interaction component. As previously pointed out, variability in rice income in Ramnad was explained more by variability in yield, while in the state and in Coimbatore and Thiruvallur, variability in income was due to price variability. Therefore, yield stabilization is much effective in keeping revenues stable in rainfed districts; while price stabilization is an effective strategy to reduce revenue risk in irrigated districts.

Income inequality (from rice) was less during the drought period in the state and in rice production environments indicating that drought has affected rice cultivation, irrespective of the region or scale of operation, i.e., small or large farmers (Table 23). Inequality is higher between the small and large farmers particularly during normal periods, as the level of production and farm size are responsible for the inequality. However, the Gini-indices estimated for the state and sample districts are lower during the drought periods, pointing to drought as the major cause of shortfall in rice production. Consequently, income obtained from rice production is lower during the drought period.

Rice is the major source of income (60 percent of the total income) in these fragile environments even during the drought period

Table 19. Rice production shortfall and price change during the drought period

Period	Production (million tons)	Change in production (lakh tons)	Wholesale price of rice* (Rs/ton)	Change in price (Rs/qtl)
Normal	5.972	0. 303 (7.28)	4935.00	252.30 (5.51)
Drought	4.994	-1.00 (-15.94)	4211.50	470.30 (11.16)

Figures in parentheses denote average of percent change over the previous period.
*Real term (1993-94 series)
1 lakh = 100,000; 1 quintal (qtl) = 100 kg

Table 20. Drought impact on monthly wholesale prices* (percent)

Month	Paddy (common)		Paddy (fine)	
	Normal period	Drought period	Normal period	Drought period
April	4.49	13.62	4.43	14.89
May	4.69	10.87	5.03	9.39
June	6.54	5.66	4.82	11.40
July	4.33	12.63	4.19	14.99
August	6.39	6.05	5.95	8.71
September	7.15	4.84	6.43	6.62
October	6.25	10.39	5.37	10.42
November	8.12	6.06	6.57	7.99
December	8.76	6.66	7.29	10.82
January	6.29	15.25	6.64	15.07
February	6.73	13.92	5.66	19.69
March	6.07	16.90	5.88	20.20

* Percentage change over the previous month
Common paddy: bold grains; Fine paddy: slender grains
Source: Secondary data

Table 21. Instability index of retail prices of rice*

Districts	Normal period		Drought period	
	Rice (common)	Rice (fine)	Rice (common)	Rice (fine)
Coimbatore	13.99	14.90	23.99	24.28
Ramnad	10.44	10.57	51.14	49.41
Thiruvallur	13.10	14.52	24.50	27.08

*Instability index = Standard deviation $(\ln(P_t/P_{t-1})$*100
Source: Secondary data

Table 22. Decomposition of variability in rice income (percent)

District	Normal period			Drought period		
	Var (P)	Var (Y)	Cov (P,Y)	Var (P)	Var (Y)	Cov (P,Y)
Coimbatore	62.66	9.84	27.5	68.4	24.03	7.57
Ramnad	37.09	52.51	10.4	37.31	71.4	-8.71
Thiruvallur	60.35	26.98	12.67	89.86	6.32	3.82
Tami Nadu	51.15	15.53	33.32	62.04	32.28	5.68

P – Price; Y – Yield; Var – Variance; Cov – Covariance
Source: Secondary data

(Table 24) and per capita income is lesser than the state average (Rs. 19,141 at 1993-94 prices).

Yearly per capita consumption of basic foodstuff in water-limited rice production environments is lesser than the state's average (rice: 110 kg; cereals: 130 kg; and pulses: 12.4 kg) (Table 25). Agriculture still has a key role in supplying adequate food at affordable prices to ensure that poverty remains low and basic nutrition is adequate in these fragile areas.

Since both agricultural production and productivity growth were also stagnant during the 1990s (the period when agricultural investment stagnated), the so-called "trickle down" benefits of agricultural growth among the rural poor were much smaller. Nevertheless, without the prior investments in agriculture, the poverty levels would have been much higher today. Diffusion of modern rice technologies and development of assured irrigation contributed to increases in household incomes and reduction in income inequalities. In this context, continued research on the development of drought-tolerant rice varieties and seed supply management are crucial. Income inequalities can be further brought down by creation of productive non-farm employment in the rainfed areas so that available family resources can be effectively used to increase overall income levels.

Cropping Pattern Change

Marginalization of farm holdings, decelerating technological advances in staple crops, declining investments in agriculture, and increasing degradation of natural resources have challenged the agricultural sector. Diversification of agriculture, in favor of more competitive and high-value commodities, is an important strategy to overcome many of these emerging challenges (Joshi et al. 2004). This strategy can be used to augment farm income, generate employment, alleviate poverty, and conserve precious soil and water resources (Von Braun 1995; Pingali and Rosegrant 1995; Chand 1996; Ryan and Spencer 2001).

Based on the rainfall distribution and availability of ground water, rainfed farmers can change their cropping pattern to mitigate the effect of drought on their yields. Cropping intensity in the state has been stable, hovering around 112 percent over the last two decades. Area under cereals was 57 percent of the total cultivated area in 1980-81; it decreased to 43.27 percent in 2003-04. Area under pulses have increased from 8 percent in 1980-81 to 10.10 percent in 2003-04. Areas under fiber crops and oilseed have declined over the same period.

Table 23. Inequality of income distribution, 1970-71 to 2000-01 (Gini index - rice)

Period	Chengalpet	Coimbatore	Ramnad	Tamil Nadu
Normal	0.371	0.354	0.404	0.364
Drought	0.482	0.306	0.344	0.262

Source: Secondary data

Table 24. Sources of income of the farm households in the rainfed rice production environment (Rs/household/annum)

Particulars	Small farmers		Large farmers	
	Normal year	Drought year	Normal year	Drought year
Total agri income	38665.99 (74.00)	28736.62 (68.41)	70562.19 (80.47)	44044.69 (65.59)
Rice income	32811.49 (62.79)	24287.49 (57.82)	60663.43 (69.18)	36789.43 (54.79)
Non-rice income	5854.50 (11.20)	4449.13 (10.59)	9898.77 (11.29)	7255.26 (10.81)
Farm labor	4256.11 (8.15)	2599.25 (6.19)	-	-
Non-farm activities	5331.02 (10.20)	7002.00 (16.67)	9000.94 (10.26)	13977.09 (20.82)
Other sources	4000.97 (7.66)	3668.76 (8.73)	8123.06 (9.26)	9125.43 (13.59)
Total income	52254.08 (100.00)	42006.62 (100.00)	87686.19 (100.00)	67147.21 (100.00)
Per capita income	10450.82	8401.32	17357.24	13429.44

Source: Household survey and www.planningcommission.nic.in

Table 25. Household* food consumption in the rainfed rice production environment (kg/household/annum)

Crops	Normal period		Drought period	
	Self-produced	Purchased	Self-produced	Purchased
Rice	403.09	104.01	293.07	192.09
Ragi (finger millet)	-	82.50	-	98.99
Sorghum	72.54	12.70	50.73	22.25
Maize (corn)	65.00	-	56.00	-
Vegetables	93.85	48.03	68.78	44.20
Pulses	75.30	14.15	63.21	24.35

*Household 5-6 persons per family

Per capita consumption: rice = 110.15 kg/yr; cereals =130.47 kg/yr; pulses = 12.79 kg/yr (*Source*: State Planning Commission).

Per capita requirement: cereals = 147 kg; pulses = 30 kg. (*Source*: ICMR)

Source: Household survey

Estimates reveal that much of the crop diversification was observed during the 1990s, as evident from the rate of growth of the Herfindhal index, which was higher (2.23 percent) during the 1990s compared to the 1980s (-3.95). To measure crop diversification, the Herfindahl index was estimated as follows:

where: $$D_t = \sum_{i=1}^{n} P_i^2$$

$$P_i = \frac{A_i}{\sum_{i=1}^{n} A_i}$$

P_i = Proportion of i[th] crop

A_i = Area under i[th] crop (ha)

$\sum_{i=1}^{n} A_i$ = Total land area

Crop diversification of high water-consuming crops, like rice, and lower water consuming crops was not reflected as the index was almost equal during the drought and normal periods. However, to some extent, crop diversification was noticed in Ramnad district with an index of 0.24 and 0.37 during the drought and normal periods respectively (Tables 26 and 27).

Farmers' decisions on how to allocate resources would depend on price expectation and productivity of crops in relation to prices and productivity of substitute crops. Since a large amount of the total water available in Tamil Nadu is used for rice production only, the potential contribution of the diversification of rice production system is justified without compromising the food security of the state. However, family food security is the primary concern of the majority of the farmers. They are willing to undertake diversification only if rice production can provide adequate food for their family. Therefore, it is necessary to increase the productivity of rice-based production systems to successfully promote crop diversification. Estimated coefficients reported in Table 28 are statistically significant at one percent level of probability except for rainfall.

The area allocated to rice cultivation depends on two major factors: price and technology. Technology results in higher productivity; and as long as productivity gains meet the household food requirements and normal profit, farmers tend to allocate rice area to other commercial crops. The estimated regression coefficient shows that an increase in productivity of rice by one ton would replace rice area by 0.189 million hectares emphasizing that cultivation of varieties with high yield potential and adaptability traits can ensure self sufficiency production for the state. Influence of rainfall distribution and productivity of rice on area allocation decisions was assessed using the following linear regression:

$$RA = b_0 + b_1 RF + b_2 FHP + b_3 GCA + b_4 PY$$

RA = Rice area (ha)

RF = Annual rainfall (mm)

FHP = Farm harvest prices (Rs/qtls)

GCA = Gross cropped area (ha)

PY = Productivity (t/ha)

Similarly, area expansion under rice was also noticed in the selected districts, revealing that infusing high productivity traits in the drought-tolerant rice varieties will enable farmers to allocate part of their land to other crops. Such diversification strategy can generate adequate income to alleviate poverty in the rainfed areas. In drought-prone and dryland areas, rainfall influences the risk-taking function of farmers to

Table 26. Drought and crop diversification (Herfindahl index)

Particulars	Drought period	Normal Period
Ramnad	0.24	0.37
Thiruvallur	0.40	0.41
Coimbatore	0.14	0.15
Tamil Nadu	0.14	0.15

Source: Secondary data

Table 27. Extent of crop diversification (Herfindahl index)

Year	Coimbatore	Ramnad	Thiruvallur	Tamil Nadu
1970's	0.11	0.17	0.54	0.15
1980's	0.13	0.35	0.53	0.14
1990's	0.10	0.47	0.45	0.14
Overall	0.15	0.37	0.41	0.15
Drought period	0.14	0.24	0.40	0.14

Source: Secondary data

a very large extent as evident from the estimated results. Rainfall has a positive influence on rice area expansion (although not significantly) and it was found that for every additional increase in rainfall by 1 mm, about 208 hectares of additional area would be brought under rice cultivation.

Several factors influence the nature and speed of agricultural diversification from staple food to high value commodities. Earlier evidence suggests that the process of diversification from staple food production was triggered by rapid technological change in agricultural production, improved rural infrastructure, and diversification in food demand patterns (Pingali and Rosegrant 1995).

Determinants indicating the demand and supply side forces of crop area diversification are included in the model to examine the nature of influence of the various factors on crop area diversification. Factors affecting crop area diversification were analyzed using the log linear equation. Rainfall, irrigation intensity, fertilizer consumption per hectare, wholesale price index, and productivity index were included in the model to examine their influence on crop area diversification.

$$HI = a\ RF^{b1}\ II^{b2}\ N^{b3}\ P^{4}\ K^{b5}\ WPI^{b6}\ PI^{b7}$$

HI = Herfindahl index

RF = Rainfall (mm)

II = Irrigation intensity (percent)

N = Nitrogen (kg/ha)

P = Phosphorus (kg/ha)

K = Potash (kg/ha)

WPI = Whole sale price index

PI = Productivity index

Herfindahl index was considered as dependent variable and Hausman (1978) endogeneity test was also performed to know if there is any endogeneity. Major sources of

Table 28. Factors affecting the rice area in Tamil Nadu – Linear estimates

Variables	Coefficients	SE	t Stat	P-value
Intercept	-1308430	541643	-2.4157	0.0245
Rainfall (mm)	208.09	133.7963	1.5552	0.1342
Farm harvest prices (Rs/qtls)	771.77	281.1441	2.7451	0.0118
Gross cropped area (ha)	0.53	0.0721	7.3951	0.0001
Productivity (t/ha)	-189208	42453.82	-4.4568	0.0002

Dependent variable: rice area in ha
R^2=0.84
qtls: quintals, 1 quintal = 100 kg
Source: Secondary data

endogeneity are omitted variables, measurement error and simultaneity. It is proven that using OLS is more efficient if there is no endogeneity. If there is endogeneity, OLS is inconsistent and so 2SLS is better. Hence, for estimating the effect of demand and supply forces on cropping pattern change, single linear equation approach was followed and OLS method was employed.

Econometric results show that rainfall has a negative effect on crop area diversification in Ramnad, revealing that good rainfall discourages diversification in rainfed areas (i.e., farmers will stick to devoting their areas to rice production). Irrigation intensity (ratio of gross irrigated area to net irrigated area) has a positive and significant effect on crop area diversification in Coimbatore, suggesting that availability of irrigation water all-year round is expected to promote crop diversification. Coefficients of wholesale price index and productivity index reveal that farmers prefer to cultivate the same crops if the practice results to higher income through increase in productivity or better product price (Table 29).

IMPLICATIONS

Rainfall influences the risk-taking function of farmers to a very large extent in dryland areas. Estimates show that the intensity of drought is higher during the first cropping season and occurs during the maximum tillering stage. These emphasize the need to develop drought-tolerant rice varieties that can withstand early drought. Although use of HYVs brought huge yield gains, yield variability still represents a formidable production risk. Landraces in the rainfed production environment continue to dominate, although the modern HYVs has made a big dent in most of the irrigated areas.

Benefits of the new technologies can be derived if they assure minimum levels of yield during the drought period because farmers tend to cut back on the use of modern inputs during such period, which may result in further decline in productivity. It is imperative that the traits (genetic and marketability) of widely adopted modern varieties and landraces are to be considered in developing desirable varieties for water limiting environments, thereby the desired income realization from rice can be sustained.

The negative correlation between prices and yields reduces crop revenue fluctuations and provides a natural hedge to farmers, but such relationship was not observed in most of the rice production environments. Variability in income in Ramnad district was explained more by variability in yield than the price both during normal and drought periods, while in the state and in the other rice production environments, variability in rice income was more due to price variability.

It is important to maximize risk-taking ability of the farmers and some studies propose several alternative solutions in this regard. There is a clamor for reducing input prices and an equal demand for raising the output prices. However, there is also concern that fixing higher prices for outputs will further perpetuate income inequalities and benefit more the large farmers who would get higher levels of profit. This suggests the possibility that perfect price stabilization would rather destabilize incomes in some areas. This would happen if the yield component is greater than the sum of price component and the price-yield interaction component.

The negative correlation between prices and yields reduces crop revenue fluctuations and provides a natural hedge to farmers, but such relationship was not observed in most of

Table 29. Effect of drought on crop diversification (autocorrelation adjusted log linear estimates)

Variable	Coimbatore	Ramnad	Thiruvallur	Tamil Nadu
Constant	-0.065 (-0.481)	1.294 (1.577)	0.353 (2.660)	0.039 (0.206)
Rainfall (mm)	-0.00001 (-0.355)	-0.0002** (-2.268)	0.000002 (0.076)	-0.00002 (-1.011)
IRR intensity (percent)	0.207** (2.012)	-0.399 (-0.428)	0.087 (0.076)	0.093 (0.594)
N (kg/ha)	0.370 (0.305)	1.255 (0.350)	0.612 (0.401)	3.783 (1.176)
P (kg/ha)	1.612 ** (2.305)	-31.544 * (-1.708)	-2.608 (-0.631)	0.203 (0.016)
K (kg/ha)	-2.496*** (-2.760)	7.894 (0.396)	-2.400 (-0.822)	-8.259* (-1.590)
Wholesale price index	-0.283 * (-1.920)	-1.003** (-2.359)	0.790*** (3.455)	-0.296 (-0.405)
Productivity index	-0.00002 (-1.864) *	-0.0001 (-1.623)	-0.00003 (-1.536)	0.00002* (1.661)
R^2	0.80	0.75	0.72	0.51
Adjusted R^2	0.70	0.61	0.57	0.28
F value	7.83	5.75	5.03	2.22

Dependent variable – Herfindahl index

***significant at 0.01 level; **significant at 0.05 level ; *significant at 0.10 level

Source: Secondary data

the rice production environments. Variability in income in Ramnad district was explained more by variability in yield than the price both during normal and drought periods, while in the state and in the other rice production environments, variability in rice income was more due to price variability. Yield stabilization would be much more effective in stabilizing revenues in rainfed areas, while price stabilization, on the other hand, is an effective strategy to reduce revenue risk in irrigated areas.

Continued research on development of drought-tolerant rice varieties and seed supply management are crucial. Further income inequalities can be brought down by creation of productive non-farm employment in the rainfed areas so that available family resources can be more effectively used to increase overall income levels.

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