State of Irrigation in Tamil Nadu: Trends and Turning Points

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Introduction

Irrigation is a vital input for food security in the State of Tamil Nadu. Rice is the major staple food, accounting for three-fourths of the consumption of food grains. Irrigation covers most parts of the rice area. In 2000, 96% of the rice production was carried out under irrigation conditions. Groundwater contributes to a major part of the irrigated area. However, recent trends of groundwater water use in the state show that its abstractions in many regions exceed the total net annual recharge (CGWB 2006). Overall, groundwater exploitation exceeds 85% of the annual recharge. Moreover, irrigated areas under tank commands, once a dominant source of irrigation in Tamil Nadu, and under canal commands are decreasing. Besides, the cropping and irrigation patterns are changing to meet the increasing demand of non-grain food products. In view of the recent trends in irrigation, meeting food security in Tamil Nadu will indeed be a major challenge.

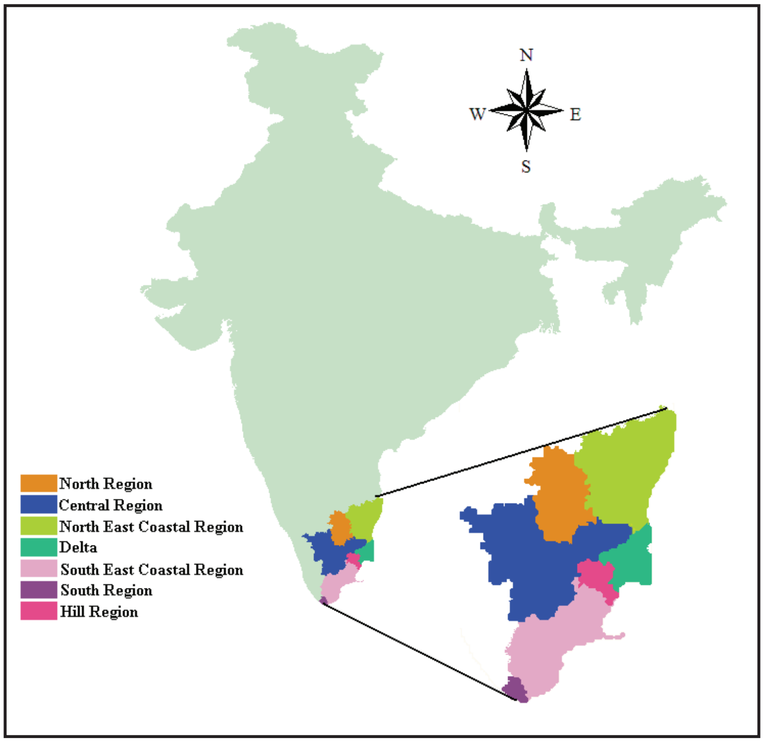
What factors have influenced these changes in the state of irrigation in Tamil Nadu, and how significant are they in the long run? Given the past trends, what types of investments in agriculture, especially in irrigation, will yield higher returns and can meet food security in the state? Answers to these questions are important for assessing future water demand, since irrigation shares more than 90% of total water withdrawals at present. The major purpose of this report is to assess the trends of irrigation development in Tamil Nadu over the last 35 years (1970-2005).

After a brief introduction to the districts and regions, in section 2 we assess the trends of major exogenous drivers that influence the water sector development. Section 3 presents the spatial and temporal trends of land use and cropping patterns, and crop production. Finally, we discuss major drivers that will influence the patterns of irrigation water use in the future.

Profile of Tamil Nadu

Tamil Nadu, located in the southeastern part of Peninsular India, with a geographical area of 13 million ha (Mha), is the tenth largest state in India (Figure 1). The state has been divided into seven agroclimatic subzones for planning agricultural development (ARPU 1991). Semiarid conditions dominate the climate in three subregions: north, northeast coastal and southeast coastal. The delta and central regions mainly have semiarid to dry-subhumid climates. These five regions consist of 97% of the total area. The average rainfall varies from 865 to 3,127 mm among subregions, and the climate of a major part of the state is categorized as semiarid to dry subhumid (Table 1).

Figure 1. Location and agroclimatic zones of Tamil Nadu.



Source: ARPU 1991.

Drivers of Change

Changing Demographic Patterns

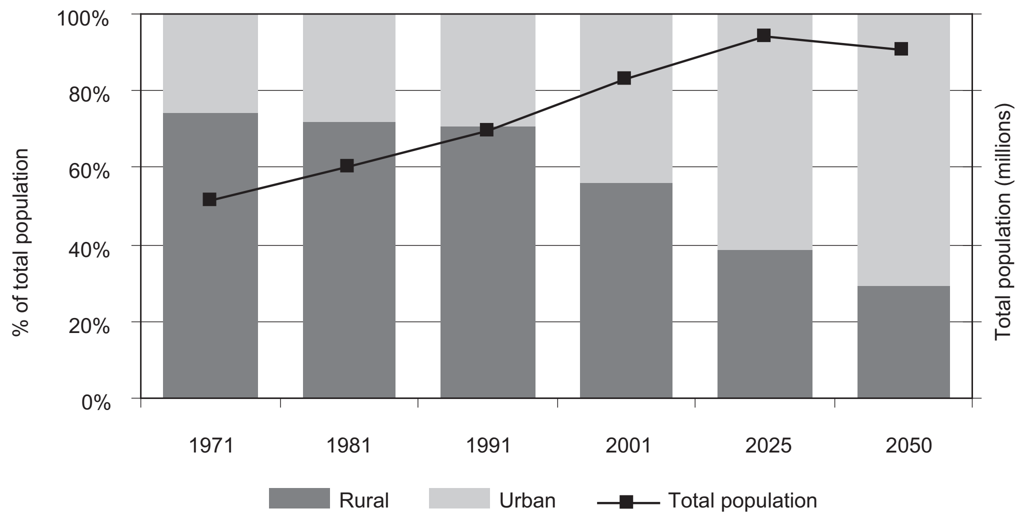
The demographic pattern in Tamil Nadu is changing rapidly, indicating major shifts in the profile of the population dependent on agriculture. In 2001, the state had a population of 62 million, accounting for 6% of India's total population and the sixth largest in all states (GOI 2001). Most (60%) of the total population still live in rural areas, but the growth of rural population became negative in the late 1990s. In 2001, the rural population was 2 million less than in 1991. Over the same period, the urban population increased by almost 12 million (Figure 2). The high growth rate of the urban population (6.1% per annum) in the 1990s indicates a substantial rural-urban migration. The data show that a majority of the population could live in urban areas before the end of this decade.

Table 1. Details of agroclimatic subregions in Tamil Nadu.

Agroclimatic subzone	District[1]	Normal rainfall (mm)	Climate	Soil types	Total population (1,000s) (rural population - % of total)			
					1971	1981	1991	2001
North	Selam	865	Semiarid	Red loamy and sandy loam	4,661 (80%)	5,439 (78%)	6,325 (78%)	7,366 (68%)
Central	Coimbatore, Madurai Trichirapalli	841	Semiarid to dry subhumid	Red and black deltaic alluvial	12,133 (69%)	14,063 (67%)	16,079 (65%)	18,451 (53%)
Northeast coastal	Chengaianna, Chennai, North Arcot South Arcot	1,036	Semiarid	Red loamy sandy coastal alluvial	10,234 (78%)	12,233 (75%)	14,601 (72%)	20,885 (51%)
Delta	Thanjavur	1,113	Semiarid to dry subhumid	Deltaic alluvial red loamy	3,833 (79%)	4,434 (78%)	4,956 (78%)	4,874 (73%)
Southeast coastal	Ramanathapuram Tirunelveli	780	Semiarid	Red and black coastal alluvial	6,052 (71%)	6,909 (68%)	7,745 (67%)	8,391 (60%)
South	Kanyakumari	3,127	Dry subhumid and perhumid	Red loamy lateritic coastal alluvial	1,228 (83%)	1,423 (83%)	1,600 (83%)	1,676 (35%)
Hills	The Nilgiris	2,226	Perhumid	Red loamy mixed red and black	491 (51%)	630 (51%)	710 (50%)	762 (40%)

[1]Districts are based on the 1991 census list.

Figure 2. Demographic trends in Tamil Nadu.



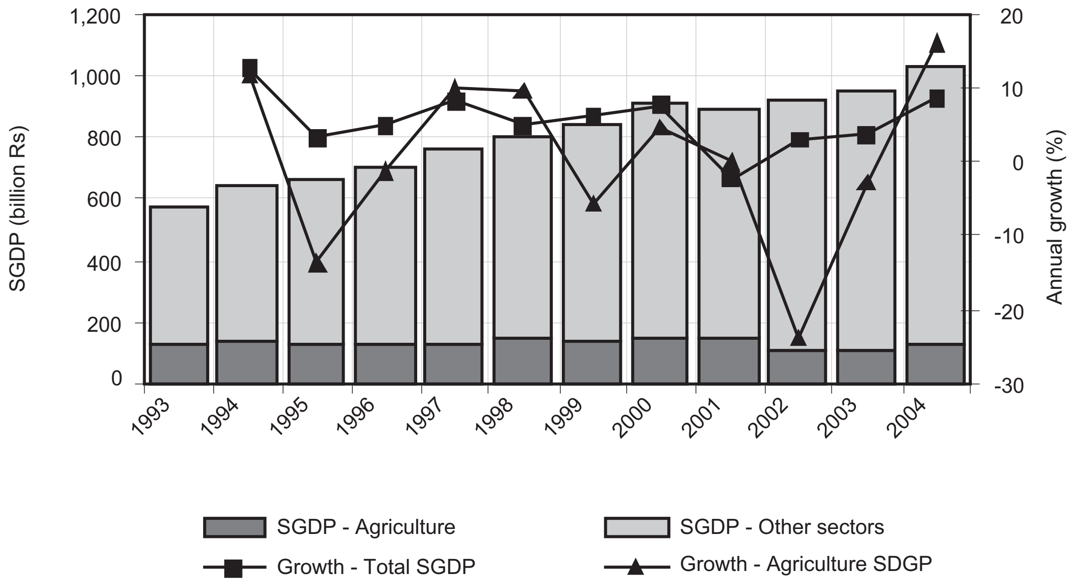
Sources: Data for 1971-2001 are from GOI 2001, and projections of 2025 and 2050 are from Mahamood and Kundu 2009.

With changing demographic patterns, dependency of rural livelihoods on agriculture is gradually decreasing. The agricultural cultivators in 2001 were 15% of the rural population, compared to 17% in 1981. However, this indicates a 0.7 million reduction in the total number of cultivators over this period. In fact, of the 21 million total workforce in 2001, only 49% were either cultivators or agricultural laborers, and the latter are only about 40% of the rural population. Such trends indicate that the contribution of the nonfarm economic activities to the overall employment has been increasing in recent years.

Economic Growth Patterns

The composition of economic growth in Tamil Nadu is fast changing. In 2005, Tamil Nadu had the seventh largest state gross domestic product (SGDP) of all the states, contributing 8% of the GDP of India. The share of agriculture in SGDP has decreased considerably over the last decade, accounting for only 12% in 2005, compared to 19.6% at the all-India level. However, annual growth of SGDP is highly variable, and the variability is largely influenced by agricultural growth (Figure 3). If growth in agricultural SGDP is very low or negative, the average growth of SDGP is 3.4%. When agricultural growth is high (>4.7%), the growth of SGDP is 8.4%, indicating that although the share of agriculture on SDGP is decreasing, high agricultural growth is a vital component for higher growth of the overall economy in the state.

Figure 3. State gross domestic product (SDGP) and annual growth.



Source: IndiaStat.com 2007.

With rapid economic growth, water demand for domestic, service and industrial sectors will increase. The total domestic and industrial water demand in India is projected to have two-threefold increases by 2050. Tamil Nadu will account for a significant part of India's additional water demand for the nonagriculture sectors. Meeting such demand in the presence of increasing water scarcities in the agriculture sector would be a serious challenge.

Changing Consumption Patterns

Food consumption patterns have been changing rapidly in recent years, affecting major changes in land use and cropping patterns. Rice is the staple food in Tamil Nadu, contributing to nutritional security of the major part of the rural population. But its consumption in both rural and urban areas has declined in recent years (Table 2). Overall, consumption of food grains per person per month has declined by 4.7% in urban areas and by 6.2% in rural areas from 1993-94 to 2004-05. This decline combined with changing demographic patterns has translated to only a 15% increase in the total demand for food grains over this period vis-à-vis a 24% growth in the total population. This reduction in demand partly explains the changing production patterns in food grains (see section 3 for a detailed discussion on cropping pattern and production changes).

Table 2. Consumption of major food items (kg/person/month) in Tamil Nadu.

Food item	Urban			Rural		
	1993-1994	2004-2005	Annual growth (%)	1993-94	2004-05	Annual growth (%)
Rice	9.25	8.58	-0.69	10.54	10.13	-0.36
Wheat	0.56	0.48	-1.29	0.22	0.20	-1.06
Other coarse cereals	0.43	0.42	-0.28	1.02	0.56	-5.33
Pulses	0.70	0.95	2.83	0.65	0.78	1.61
Total food grains	10.94	10.43	- 0.44	12.43	11.66	-0.58
Groundnut oil	0.27	0.15	-5.38	0.24	0.23	-0.39
Other edible oil	0.06	0.41	18.96	0.01	0.21	31.71
Sugar	0.65	0.69	0.52	0.46	0.49	0.50
Milk	3.95	4.82	1.83	2.11	2.48	1.48
Poultry	0.03	0.13	14.50	0.02	0.09	14.42
Eggs (numbers)	2.67	2.71	0.14	1.11	1.59	3.33

Sources: NSSO 1996, 2007.

The changes in consumption of non-grain food, which is also significant between 1993 and 2004, also influenced major changes in the cropping patterns. Over this period, consumption of milk, poultry and eggs has increased by 34%, 373% and 33%, respectively, showing a significant increase in demand. With increasing feed demand, the area under maize had a 14-fold increase between 1970 and 2005. Similarly, consumption of fruits and vegetables also increased significantly, increasing area under fruits and vegetables by 234% over the same period. With increasing income and lifestyle changes, the consumption patterns will experience further changes. As a response, cropping patterns will also undergo further changes. Next, we assess how the agriculture sector responded to these major drivers of change.

Irrigation and Crop Production: Trends and Turning Points

This section explores trends and turning points of irrigation and crop production between 1970 and 2005. The source of cropping patterns and crop production from 1971 to the late 1990s is the International Crops Research Institute for Semiarid Tropics (ICRISAT 2000), Hyderabad. The data from the late 1990s to 2005 are from two websites, namely (dacnet.nic.in/eand) of the Directorate of Economic and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India (GOI 2007), and (www.indiastat.com) of India Stat.com (IndiaStat.com 2007). This analysis only considers rainfall data of agroclimatic regions, for which the monthly estimates are available in the website of the Indian Institute of Tropical Meteorology (www.tropmet.res.in) (IITM 2007).

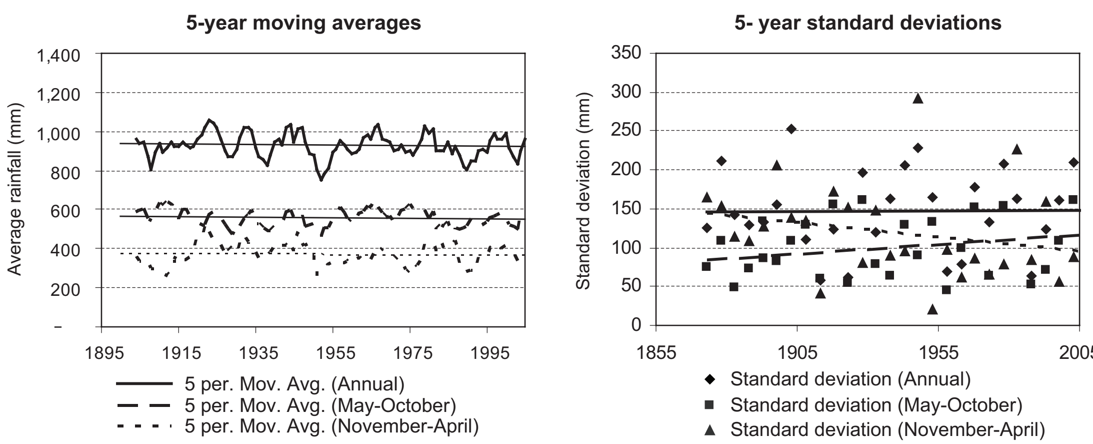
Rainfall within the state is a key determinant for both surface water and groundwater irrigation. Therefore, first we assess the long-term trends of the average seasonal and annual rainfall and their variability. Next, we explore how these rainfall trends influenced the trends of cropping and irrigation patterns in Tamil Nadu and its agroclimatic subregions. We use piece-wise linear regressions[1] for assessing the turning points and trends thereafter.

Rainfall Patterns

Bi-monsoonal patterns dominate rainfall in the sub-agroclimatic zone of Tamil Nadu. Being situated on the eastern side of the Western Ghats, most parts of Tamil Nadu miss a substantial part of dependable rainfall in the southwest monsoon. However, the southwest monsoon contributes to 60% of the annual rainfall of about 925 mm. But the southwest monsoon has high interannual variability, with a coefficient of variation close to 35%, as against 20% in the northeast monsoon. Even with the high variation of monsoonal rainfall, irrigation has played a valuable role in agricultural development in Tamil Nadu.

Long-term records show nonsignificant trends in average annual or seasonal rainfall in the agroclimatic region of Tamil Nadu (Figure 4). However, the standard deviation (over 5-year periods) of seasonal rainfall has changed over time. The variability of rainfall in the southwest monsoon (from May to October), which is most critical for crop production, has increased in recent years.

Figure 4. Annual and monthly rainfall between 1886 and 2005 in the agroclimatic subdivision of Tamil Nadu.



Source: IITM 2007.

In the past, tanks played a major role in holding the rainwater of the southwest monsoon for irrigating crops in the *rabi* (October-March) season (Gomathinayagam 2005). However, increasing variability of southwest monsoons seems to have had a significant effect on surface

[1]The piece-wise regression model takes the form

$$y_t = \alpha_0 + \alpha_1 D_{1t} + \alpha_2 D_{2t} + \beta_0 T_t + .. + \beta_1 (T_t - T_1) D_{1t} + \beta_2 (T_t - T_2) D_{2t} + .. \\ + \gamma_0 RF_t + \gamma_1 RF_{t-1} + \gamma_2 RF_{t-2} + \gamma_3 StDev(RF)_t \varepsilon$$

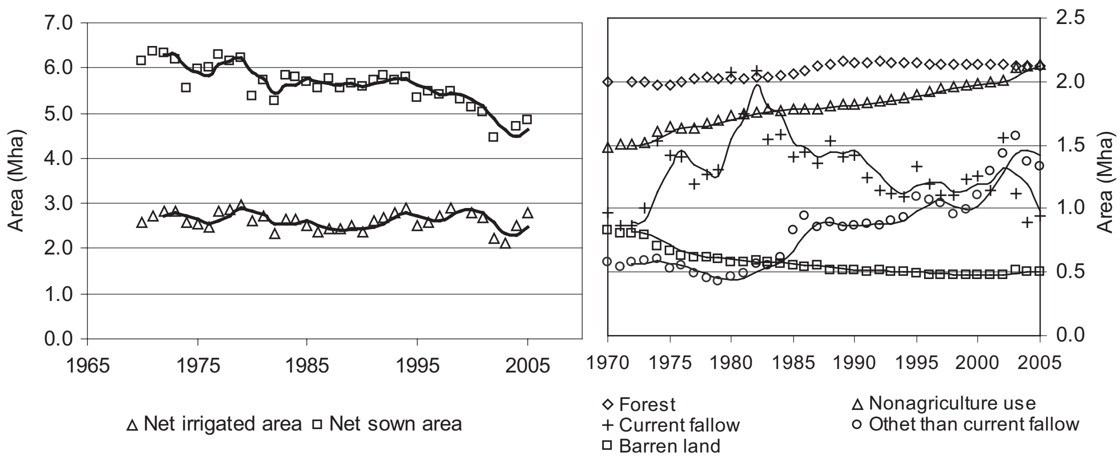
where, the indicator functions $D_{it} = I_{[t \geq T_i]}$, taking values 0 when $t < T_i$ and 1 when $t \geq T_i$, show major turning points of trends; T_t is the time trend; β_1 and β_2 show the extent of changes in trends from that before turning points; RF_t is the annual or seasonal rainfall, $RF_{t-1,}$ the lagged rainfall variables, and $StDev_t$ the standard deviation of 5-year rainfall periods.

irrigation, especially of those under tanks. As a way of mitigating the effects of increasing variability of rainfall, and also for meeting the increasing demand for irrigation, groundwater irrigation has rapidly expanded. But recent changes in many other key drivers may have had a significant effect on irrigation landscape in Tamil Nadu. We explore these in the following subsections.

Land-Use Patterns

Net sown area The net sown area (NSA) seems to have followed three distinct trend[2] patterns between 1970 and 2005 (Figure 5). The NSA has decreased at an annual rate of 0.77% during the 1970s, remained steady until the mid-1990s, and started declining again, at 2.1% annually, after 1995. Overall, the total NSA of the state has declined by 25%, or 1.5 Mha, from 6.3 Mha in 1971 to 4.8 Mha in 2005.

Figure 5. Land-use patterns in Tamil Nadu.



Among major agroclimatic subregions, the NSAs of all regions except the delta were declining (Table 1). The central region has not only the largest share, one-third of the total NSA in 2005, but also the largest contribution to the decline of about 28% between 1970 and 2005. But the biggest drop of NSA was in the northern region, where it declined by more than 40% of its peak in the early 1990s. Only the NSA in the delta region, which contributed to about 15% of the total NSA in 2005, has increased over the last three decades.

Rainfall was significant in explaining the annual variation of the average NSA. A plausible explanation for declining trends of NSA is that part of the NSA was converted to

[2]$NSA_t = 4504 - 74^* T_t + 104^* T_{[t>1981]} - 120^* T_{[t>1991]} + 1.16^* AN\_RF_t + 0.47^* AN\_RF_{t-1} + 0.46^* AN\_RF_{t-2}$. where AN_RF is the annual rainfall, AN_RF_{t-1} and AN_RF_{t-2} are lag values of orders 1 and 2 of annual rainfall, T_t is the time trend, and * indicates statistical significance at 0.05 level. All variables in the regression are statistically significant in explaining the variation of the NSA.

nonagricultural use[3] and another significant part left as fallow for long periods of up to 1-5 years (Figure 5). The nonagricultural land (NAGL) has increased by 0.6 Mha, or 42%, between 1971 and 2005. The central and northeast regions have the highest share (27% and 26%) of NAGL and also the highest contribution (39% and 38%) to the overall increase. In fact, the NAGL of these regions has increased by 61% since 1971. Over the same period, land in the category, other than current fallow, has increased by 0.79 Mha while barren land has decreased by 0.3 Mha.

Net irrigated area. No significant trend in net irrigated area (NIA[4]) existed between 1970 and 2005 (Figure 5). Annual rainfall and lagged rainfall up to the two previous years are significant in explaining the variations of NIA. The significance of lag rainfall variables mainly shows negative effects of droughts on NIA. However, with the decline in net sown area, the share of NIA in NSA increased from 42% in 1970 to 56% in 2005.

The central and northeast coastal regions have trends of NIA similar to that of the state, and share 60% of the total NIA (Annex Table 1). That is, there are no significant trends of NIA in these two regions, except for the effects due to low rainfall patterns in consecutive years. However, NIAs of the delta and southeast coastal regions have significant declining trends, with 16% and 11% drops, respectively, from the level in the 1970s. On the other hand, NIA in the northern region, with a share of 7% of the total, has increased by 40% from 1970, and has offset the drop of NIA in other regions.

Source-wise contribution to NIA. Groundwater irrigation expanded rapidly between 1971 and 2005. Canals and tanks were the main sources of irrigation in the 1970s and 1980s, contributing to about two-thirds of the total NIA. But, groundwater has been dominating irrigation since the mid-1990s, contributing to more than half the NIA in 2005 (Figure 6).

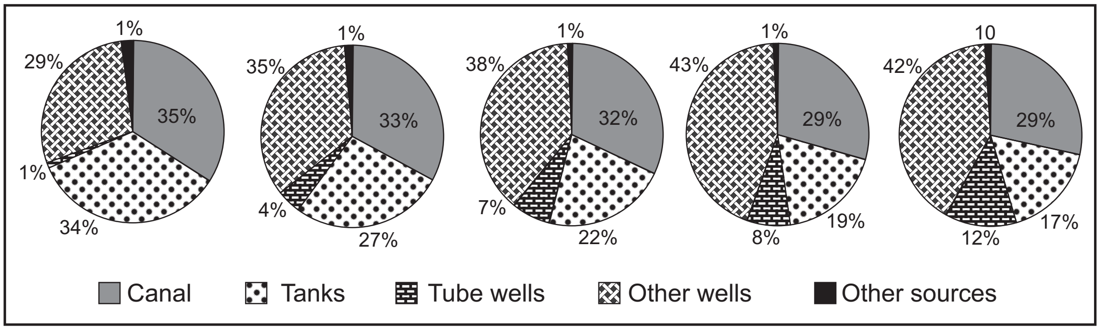
Canal irrigation commands,[5] which have lost more than 140,000 ha between 1971 and 2005, account for only 29% of the total canal NIA (Annex Table 2). The central and deltaic regions contribute to 84% of canal NIA in 2005. Half of this loss was in the deltaic region, contributing to 52% of the total under canal commands in 2005. The central region, with the second highest canal irrigated area, also lost about 20,000 ha, but it is only 12% of the total decline in the canal NIA.

[3]Nonagricultural land included under industries, housing, roads, railways, etc.

[4]$NIA_t = 5{,}299^* + 0.65^* \, AN\_RF_t + 0.56^* \, AN\_RF_{t-1} + 0.52^* \, AN\_RF_{t-2} - 2.1 \, T_t$. Annual rainfall and its lag values are statistically significant in explaining the variation of NIA, but the time trend is not significant.

[5]$Canal\text{-}NIA_t = 22.5 + 0.00024^* An\_RF_t - 0.008^* \, T_t$. Rainfall is a significant variable for explaining the variation in net canal irrigated area, but there is a statistically significant declining trend during1971-2005.

Figure 6. Share of source-wise net irrigated area.



Tank irrigation,[6] which contributed to one-third of the total NIA in 1971, has lost more than half of its NIA by 2005 (Annex Table 2). The northeast and southeast coastal regions share three-fourths of the NIA under tanks. And these two regions lost more than 54% and 24%, respectively, of NIA under tank commands between 1971 and 2005. The central region, with 15% of total tank NIA, lost more than 27% area over the same period. Although low rainfall in three consecutive years explains the short-term variation, there seems to be a consistent declining trend in the recorded NIA under tanks during the last few decades.

However, not all of the NIA lost under tank irrigation systems, was lost from the production system. Wherever the net tank irrigated area has decreased, much of that is replaced by groundwater irrigation. This is especially true in central and northeast coastal regions, where net tank irrigated area has decreased by 103,000 and 242,000 ha, respectively, while the net groundwater irrigated area has increased by 194,000 and 307,000 ha, respectively. It seems that tanks in these areas are operating as a valuable recharge structures for utilizing groundwater irrigation.

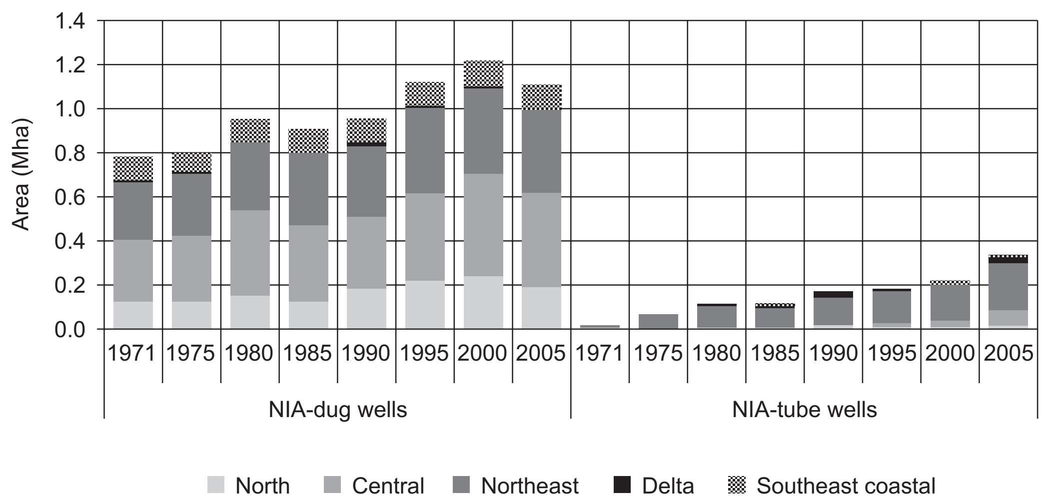
Groundwater irrigation, which has contributed to a major part of NIA in recent years, had some notable trend patterns between 1971 and 2005.

- First, groundwater has replaced part of surface irrigation, especially a part of the area under tank irrigation. This pattern is prominent in the northeast coastal and central regions (Annex Table 2), where the NIA under tank commands has decreased by 243,000 and 103,000 ha, respectively, and NIA under canal irrigated areas has decreased by 38,000 and 10,000 ha, respectively. Over this period, the NIAs under groundwater in the two regions have increased by 303,000 and 195,000 ha, respectively, and have offset the loss of surface irrigated area.
- Second, groundwater irrigation has also spread well outside surface command areas. Increases in net groundwater irrigated area in central and northeast coastal regions far exceed the loss of area under surface irrigation. In the north region, increase in groundwater irrigated area is even higher than the combined area of canal and tank irrigation. Indeed, these excess groundwater irrigated areas must have occurred outside the surface command areas.

[6] $Tank\text{-}NIA_t = 48.24 + 0.05^* AN\_RF_t + 0.03^* AN\_RF_{t-1} + 0.02^* AN\_RF_{t-2} - 0.02^* T_t$. Annual rainfall and rainfall in the two previous years explain the variation in net tank irrigated area. However, in spite of these contributions, there was a significant declining trend of NIA under tank commands during 1971-2005.

- Third, recent growth patterns indicate that groundwater irrigation especially that through dug wells, is not sustainable in many regions. Dug wells were the main contributor to the growth of groundwater irrigation before late 1990s (Figure 7, right-hand graph). However, the NIA through dug wells has been decreasing in recent years. Part of this decline was due to the droughts of 2001-2003. But the declining trend seems to be continuing beyond the drought period.
- Fourth, it is clear that reliance of tube-well irrigation is increasing. In fact, tube-well irrigation seemed to be taking the place of dug wells in most regions (Figure 7, right-hand graph). The central and northeast coastal regions had the largest increase with each region recoding 34,000 ha of additional net tube-well irrigated area between 2000 and 2005. The central and northeast coastal regions had, respectively, tenfold and twofold increases in tube-well irrigated area between 1971 and 2005. Although small in magnitude, the north region also nearly doubled its tube-well irrigated area from 2000 to 2005.

Figure 7. Net dug well and net tube-well irrigated areas in agroclimatic subregions.



Impacts of groundwater development. Although groundwater development has contributed to maintaining NIA at the present level, it has led to environmental concerns in many regions. As a whole, 85% of the net groundwater resource is already developed (Annex Table 2). However, many regions are categorized as overexploited, where groundwater withdrawals far exceed the net available resources. Of the 385 blocks, 142 are overexploited. And 33 blocks are categorized as critical, where the stage of development is between 90 and 100% in both pre- and post-monsoons, and 57 are semi-critical, where the stage of development is between 70 and 100% in either pre- or post-monsoons (CGWB 2006).

Many of the blocks in the north, central and northeast coastal regions are either critical or overexploited. These regions have 74% of the net available groundwater resources of the state, but contribute to 89% of the NIA under groundwater. Indeed, sustaining groundwater irrigation at the present level is a major issue in these regions. In fact, after a continuous growth, the NIA under dug wells in all three regions has decreased between 2000 and 2005 whereas that under tube wells has increased over the same period and helped maintain a positive growth in area under groundwater irrigation.

However, with the present trends of falling groundwater tables, how long these growth patterns of groundwater irrigation can be maintained is a critical issue.

Gross irrigated area. Although the NIA remains a constant, the gross irrigated area (GIA) showed a statistically significant declining trend[7] between 1971 and 2005 (Figure 8). This indicates that the area that is irrigated more than once has declined over the last few decades. In fact, the irrigation intensity, the ratio of GIA to NIA, has declined from 131% to 112% between 1971 and 2005. As a result, the GIA has declined by 0.49 Mha, from 3.47 Mha in 1971 to 2.98 Mha by 2005.

The sharp decline[8] of irrigation intensity and hence GIA started since the mid-1990s. Part of this decline, especially the trends after 1995, can be attributed to low rainfall. But the statistically significant time trend indicates that other factors are also contributing to decrease GIA by about 3,500 ha annually. These factors include the increasing demand for water from other sectors in dominantly canal irrigated areas, and increasing variability of water supply and water scarcities and low profitability in tank irrigated areas. In fact, the largest contributions to the decline of GIA are from the delta—a region dominantly canal-irrigated, and the northeast coastal subregion—a region dominantly tank-irrigated. In both regions, GIA has decreased by 0.21 Mha (Annex Table 3). In 1971, canals contributed to 93% of the irrigation in the deltaic region, while tanks contributed to more than half the irrigation in the northeast coastal region.

Table 3. State of groundwater development.

Agroclimatic subregion	Annual replenishable groundwater resources	Net groundwater availability[1]	Annual groundwater withdrawals			Stage of groundwater development[2]
			Irrigation	Domestic and industries	Total	
	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(%)
North	24.8	22.3	27.8	1.0	28.8	129.1
Central	58.5	52.6	41.6	2.3	43.9	83.4
Northeast coastal	89.4	80.4	75.7	3.0	78.7	97.9
Delta	13.8	12.4	9.5	0.8	10.3	82.8
Southeast coastal	30.4	27.4	11.1	1.1	12.2	44.7
South	2.9	2.6	0.2	0.2	0.4	16.2
Hill	10.9	9.8	1.9	.3	2.1	21.7
Tamil Nadu	230.7	207.7	167.8	8.8	176.5	85.0

Notes: [1] Net groundwater availability is the difference between annual replenishable groundwater resources and natural discharge during non-monsoonal months

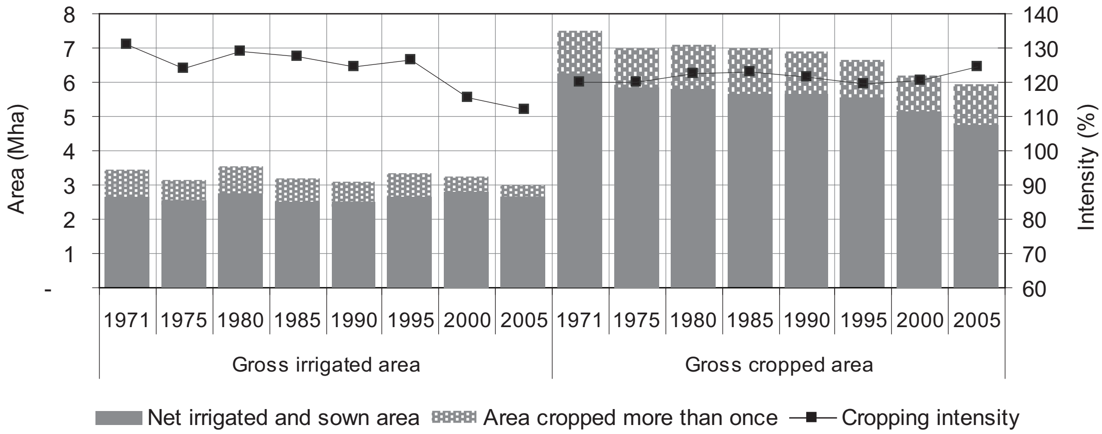
[2] Stage of groundwater development is the ratio of groundwater withdrawals to net groundwater resources

Source: Authors' estimates based on CGWB 2006.

[7] $GIA_{it} = -50.1 + 1.18^{*} NIA\_CAN_{it} + 1.23^{*} NIA\_TANK_{it} + 1.65^{*} NIA\_TW_{it} + 1.16^{*} NIA\_DW_{it} + 0.08^{*} RF\_AN_{t} + 0.05^{*} RF\_AN_{t-1} - 3.5^{*} T_{t};\ R^2 = 95\%$. * indicates that the coefficients are statistically significant at the 0.05 level.

[8] $II_{t} = 95.1^{*} - 0.05\ T_{t}\ 1.5^{*}\ T_{[t>1995]} + 0.02^{*} RF\_AN_{t} + 0.01^{*}\ RF\_AN_{t-1};\ R^2 = 70\%$.

Figure 8. Gross irrigated area and irrigation intensity.



An increase in GIA was registered only in the north region. Groundwater, which contributed to two-thirds of the irrigated area in 1971, has sustained the expansion of irrigation in this region. Our analysis showed that NIAs under canals, tanks and dug wells have contributed more or less the same for expanding the GIA, where each additional ha of NIA added 1.16–1.23 ha to the GIA. However, with greater ability to pump water from deep aquifers, each hectare of net tube-well irrigated area contributed an additional 0.65 ha to the GIA.

Gross cropped area. The gross cropped area (GCA) also registered a declining trend[9] (Figure 8) similar to that of the net sown area (NSA). The GCA declined in the 1970s, remained steady during 1980s, and began declining again in the mid-1990s. Overall, GCA declined by 21%, or 1.58 Mha between 1971 and 2005 (Annex Table 3), to which the decline in NSA has contributed 94%. This shows that there are no major changes in cropping intensity (CI), ratio of GCA to NSA. The CI was 124% in 2025, compared to 120% in 1971.

The GCA has declined significantly in all regions except in the north, where it slightly increased by about 0.2 Mha. The central and southeast coastal regions have the largest share of GCA (about 54%), and are also the largest contributors to the decline in GCA (about 68%).

Cropping patterns. No major crop diversification trends from grain to non-grain crops exist in Tamil Nadu (Figure 9). Although grain-crop area has declined by about 1.41 Mha between 1971 and 2005, non-grain area has no commensurate increase over this period. In fact, the decline in food-grain area has contributed to 89% of the overall reduction in the GCA, decreasing the share of food grains in the GCA from 63% to 54% over this period.

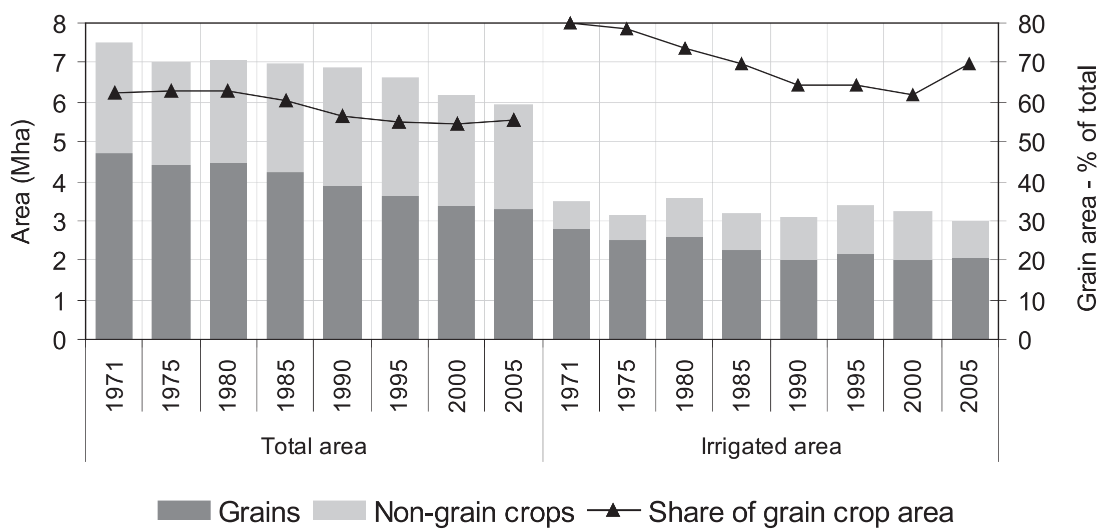
The share of non-grain crops in the GCA increased from 37% to 45% from 1971 to 2000. However, this increase was primarily due to the reduction in area under food-grain crops. In fact, the area under non-grain crops had slightly increased before 1990, but again decreased to the level of the early 1970s. However, a change towards crop diversification occurred in the north region, where increase in area under non-grain crops exceeded the decline in area under food-grain crops by about 195,000 ha (AnnexTable 3). The expansion of groundwater

[9] $GCA_t = 4875 - 87^{*}\, T_t + 121^{*}\, T_{[t>1980]} - 148^{*}\, T_{[t>1995]} + 1.78^{*}\, AN\text{-}RF_t + 0.84^{*}\, AN\_Rf_{t-1} + 0.57^{*}\, AN\_RF_{t-2}$; R^2= 86%. * indicates statistically significant at the 0.05 level. Changes in trends from the 1970s, 1980s, and 1990s are statistically significant. Overall, there is a statistically significant declining trend of GCA.

irrigation, which dominates the land-use patterns in the north region, has contributed to this increase.

Although no major changes occurred in the overall share of GIA in the GCA, the share of irrigation in grain and non-grain crops changed sharply. Close to 80% of the GIA was under food-grain crops in 1970 and this share had decreased to 60% by 2000. This means that much of the reduction in irrigated area under food-grain crops was replaced by irrigated area of non-grain crops. In fact, between 1970 and 2000, the non-grain-crop area increased by 539,000 ha, while the grain-crop area declined by 785,000 ha. Similar trends of irrigation patterns exist in all agroclimatic regions, indicating changing preference for using scare irrigation resources, especially groundwater, for high-value non-grain crops.

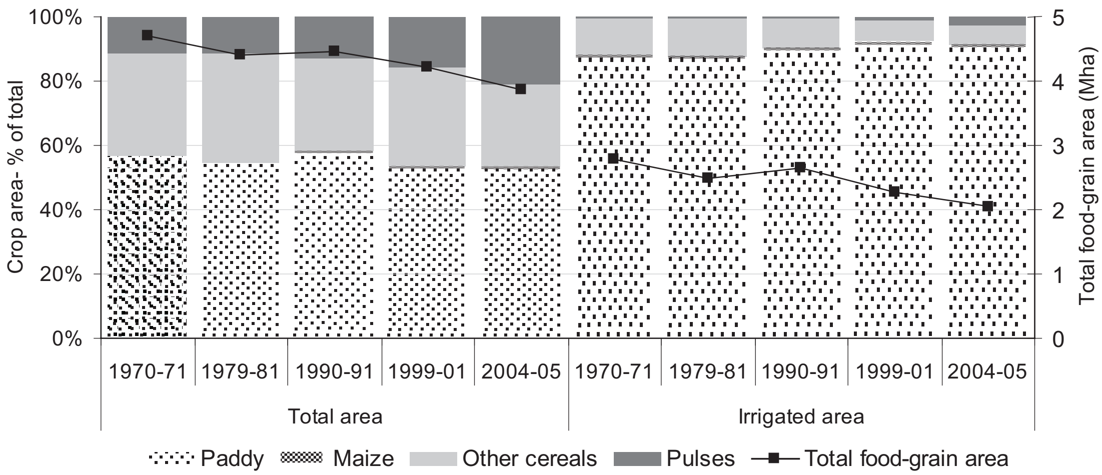
Figure 9. Cropping and irrigation patterns.



Cropping Patterns of Food Grains

Paddy dominates the cropping pattern of food grains, accounting for 60% of the total food-grain area, and more than 80% of the total food-grain irrigated area in 2005 (Figure 10). However, area under paddy has decreased over time, by 0.67 Mha of the total and by 0.64 Mha of irrigated area since 1970 (Annex Table 4). This contributed to a major part of the decline in GCA and GIA.

Figure 10. Changing cropping patterns of food-grain crops.



Although the total paddy area has decreased, the share of food grains has remained steady over time. This is primarily due to the declining area under coarse cereals. The area under coarse cereals has also declined by 64%, from 1.48 to 0.54 Mha between 1971 and 2005. Only the area under maize has increased over this period. The growth in maize area is only a recent phenomenon, and the total area under maize has more than doubled between 2000 and 2005, indicating increasing demand for livestock feed.

As in the total area, paddy dominates the irrigated area under food grains. In fact, the share of irrigated area under paddy has increased slightly, from 88% in 1970 to 94% in 2000. Irrigated area under food-grain crops, except maize and pulses, has decreased over this time. Irrigated area under maize, although small in comparison to other crops, has an eightfold increase between 1970 and 2005. This trend is expected to increase with increasing feed demand, which primarily emanates from increasing consumption of poultry products.

In fact, the changes in cropping patterns seem to be quite parallel to the changes in food consumption patterns. While the consumption of cereals is decreasing, the preference for non-grain food crops, such as vegetables and fruits, and animal products, especially for milk, poultry and eggs is increasing. The consumption of rice per person per month in urban and rural areas has slightly decreased by 0.68 and 0.41 kg, or 7% and 4%, respectively, between 1993-94 and 2004-05. And the consumption of coarse cereals has dropped drastically, especially in rural areas by about 0.46 kg or 46%. Over the same period, consumption of milk has increased by 22% and 18% in rural and urban areas, respectively, with the consumption of poultry products increasing more than threefold. The latter has increased the demand for feed, particularly for maize.

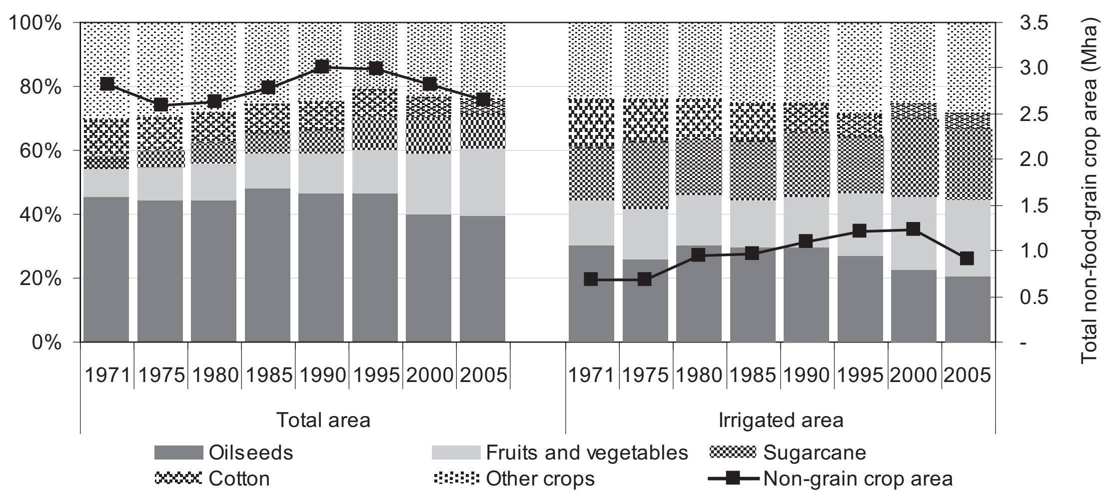
With increasing income and changing lifestyles, food consumption patterns are expected to change further (Amarasinghe et al. 2007). As a result, consumption demand, and hence the production requirement and area of coarse cereals could further decrease. The consumption demand for rice will also decrease slightly. Thus, as in the last two decades, additional demand for rice will be met primarily through increase in yield rather than through increase in area. However, area under maize will increase manifold to meet the increasing feed demand.

Cropping Patterns Non-Grain Crops

Although the total area has not increased, major changes in cropping and irrigation patterns of non-food-grain crops have occurred since the 1990s. The areas under oilseeds, once dominated non-food-grain cropping patterns, but area under cotton has decreased (Figure 11). The area under fruits, vegetables and sugarcane has more than doubled and virtually replaced the area of production of other non-food-grain crops. The area under fruits and vegetable has increased in all but the deltaic region, and area under sugarcane has increased in all regions (Annex Table 5). The area under oilseeds has declined significantly in central and northeast coastal regions, while the area under cotton has declined significantly in central and southeast coastal regions.

Although the total crop area of non-food-grain crops shows no major change, the area under irrigation increased significantly between 1971 and 2000. Only one-quarter of area under non-food-grain crops was irrigated in 1971, and this has increased by 43% by 2000. Fruits/vegetables and sugarcane contributed to a major part of additional irrigated area in non-food-grain crops, increasing by 171,000 and 175,800 ha, respectively, between 1971 ad 2000.

Figure 11. Cropping patterns of non-food-grain crops.

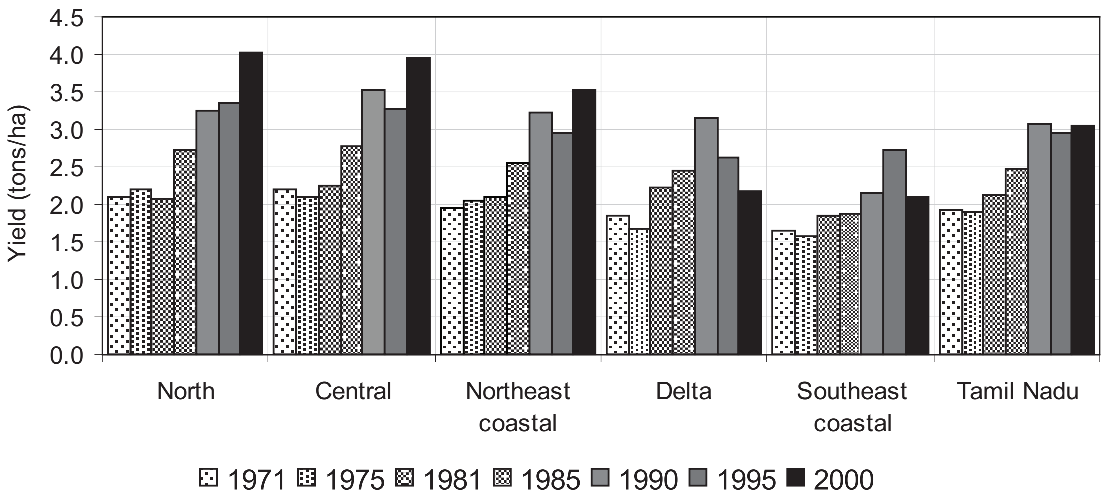


The decline in irrigated area under non-food-grain crops between 2000 and 2005, of about 320,000 ha, shown in Figure 11 may, in fact, not reflect the long-term trends. This decline is mainly due to slow recovery of irrigation in non-food-grain crops after the severe droughts between 2001 and 2003. In fact, total area under irrigated non-food-grain crops between 2000 and 2003 has declined by 458,000 ha. But with good rainfall, the declining trend was reversed and the area under irrigated non-food-grain area recovered 138,000 ha during 2004-2005. If changing consumption patterns and increasing income are indicators of future direction, the trends of increasing irrigation patterns in non-food-grain crops will most probably expand in the future. Per capita consumption of fruits and vegetables is significantly higher in urban areas than in rural ones (21% and 52%, respectively); and it increases significantly with increasing income (NSSO 2007). Thus, Tamil Nadu is rapidly changing its rural and urban structure, with increasing income. Therefore, demand for fruits and vegetables will further increase in this state.

Crop Productivity

Growth of crop productivity varies between crops and also between regions. Paddy is the major crop in Tamil Nadu, and almost the whole paddy area is irrigated. Paddy yields increased only marginally in the 1970s, and significantly (3.77% annually) in the 1980s. However, the growth in yield[10] as a whole stagnated in the 1990s (Figure 12). This is primarily due to decreased yields in the deltaic region, where canal irrigation dominates, and the stagnant yields in the southeast coastal region, where tank irrigation dominates. These two regions had 42% of the paddy area, contributing to 30% of the total paddy production in 2000. The paddy yields in the other three major paddy-producing regions, where groundwater irrigation dominates, have increased even in the 1990s.

Figure 12. Paddy yields in different agroclimatic regions (tons/ha).



Increasing reliability of irrigation supply in groundwater irrigated areas may be a factor in sustaining yield increase in the north, central and northeast coastal regions. In fact, the contribution from groundwater irrigation to the overall yield growth is about three times that of canal irrigation. The reliability of irrigation supply seemed to be lowest in canal irrigated area, where yield has been declining since 1990, as is indicated in the deltaic region. Increasing groundwater irrigation in tank command areas could have somewhat offset the negative impact due to unreliable water supply in tank irrigation, as is evident in the southeast coastal region. Changes in trends of yields of other crops are also observed in Tamil Nadu (Annex Table 6). Among these, yields of:

- sorghum, a prominent coarse cereal crop in north and northeast coastal regions, had a slight declining trend of 1.2% annually in the 1990s,
- pearl millet and finger millet, which are prominent coarse cereal crops in the north and northeast, had a slightly increasing trend of 1.6% annually in the 1990s,

[10] $Paddy\_yld_{it}=1.87^{*}+0.0038^{*}Fertha_{it}+0.0056^{*}PctCanal_{it}+0.0154^{*}PctGW_{it}+3.67\ Roadha_{it}+ -0.018^{*}StdveRF_{it}-0.007T_{t}+0.058^{*}T_{t[t>1980]}-0.082^{*}T_{t[t>1995]}$., where i=1,..5, stands for north, central, northeast coastal, deltaic and southeast coastal regions; $Fertha_{it}$ is the chemical (NPK) fertilizer use per gross cropped area; $PctCanal_{it}$ and $PctGW_{it}$ are net irrigated areas under canal and groundwater as a percent of net irrigated area; $StdevRF_{it}$ is the standard deviation of monthly rainfall. * indicates statistical significance at the 0.05 level.

- pulses are stagnating in all regions except the north,
- oilseeds were gradually increasing by 1.21% in the 1980s and by 2.34% in the 1990s; Groundnut is the major oilseed crop in the state, contributing to 94% of the total oil seed production and its yield increased by 3.2% annually in the 1990s,
- sugarcane, a prominent crop in the state, had no significant yield increases since 1980, and
- cotton increased by 4.2% in the 1980s and by 7.8% in the 1990s; the spreading of BT cotton has contributed to the sharp growth in yield in the latter period; this has contributed to increase cotton production by 42% between 1990 and 2000, although area under cotton declined by 36% over the same period.

Declining productivity and crop area have had a severe effect on the state's situation in food-grain security. Supply of food grain in 2004-05 was only 65% of the demand, in comparison to 96% in 2000. Importantly, rice production has dropped drastically, 31% over this period, accounting for only 61% of the demand in 2004.

Discussion of Future Scenarios

In this section, we discuss a few future scenarios emerging from recent trends or to explore in the irrigation sector in Tamil Nadu.

- The NSA of the state has been declining, and nonagricultural uses have taken up part of the decreased area. With rapidly increasing urban population and expanding industrial and service sectors, this trend is expected to continue.
- A part of the NSA area was also left fallow for an extended period of time. Increasing migration of agricultural labor to nonagriculture sectors, decreasing the agriculture-dependent population and increasing competition for water from other sectors could aggravate this situation. Although no visible trends exist at present, opportunities for land consolidation for increasing economies of scale in land use in agriculture could emerge in the future.
- With increasing competition for surface water from other sectors, maintaining area under major/medium irrigation schemes at the present level could be a serious challenge. It is likely that net irrigated area under major/medium irrigation would further decrease. And most of the surface irrigation under major/medium schemes will be confined to high productive and high potential areas. Moreover, as a solution to the declining irrigated area, changing operations of irrigation deliveries to increase adoption of water saving technologies or changing to low-water-intensive cropping patterns needs to be explored.
- Increasing variability of rainfall and unreliable surface irrigation supplies are major causes for declining tank irrigated area. Many small tanks cannot offer adequate irrigation supply for even a single season. Thus, command area under tanks will decrease further. However, many of these tanks can be used as water recharge structures for groundwater irrigation. They will provide a better control of on-farm water use in irrigation. Additionally, it will be a reliable drinking water supply for human beings and livestock in tank command

areas. Thus, it is likely that groundwater irrigation will increase in the tank command areas.

- In spite of the declining water tables, the number of dug wells and tube wells in most regions are increasing, albeit at a slower rate. Groundwater irrigation has better control of water use and can, in turn, contribute to higher crop productivity than surface irrigation. Augmenting groundwater supply for maintaining or expanding groundwater irrigation should be a key plank of the state water policy. Artificial groundwater recharge should be promoted to the extent where there is no impact on downstream water users. These will have major spatial distributional impacts on agriculture-dependent livelihoods.
- Micro-irrigation techniques improve water-use efficiency, reduce irrigation demand and improve crop productivity. Yet, only about 66,000 ha of cropped area use drip and sprinkler irrigation (Narayanamoorthy 2009), which is only 4% of the net area under groundwater irrigation. In general, groundwater irrigation is conducive to adopting micro-irrigation. Groundwater is the source for a large part of irrigated area of non-grain crops such as vegetables, fruits and sugarcane. These crops and areas have the largest potential for adopting drip and sprinkler irrigation in India.
- Decreasing per capita demand, water scarcities and low prices are major reasons for decreasing paddy area. Paddy area seemed to have stabilized at around 2 million ha, and most of that are irrigated. Providing a reliable irrigation supply to support paddy growing in this area will be a key challenge. Water saving techniques, such as system of rice intensification (SRI) or aerobic rice (AR), reduce the irrigation demand and, in most cases, improve crop productivity. With increasing water scarcities, the demand for introducing water saving techniques in paddy cultivation will increase.
- Food demand for coarse cereals is decreasing. Thus, the area under other cereals is also decreasing. This trend will likely continue into the future.
- Demand for feed crops, such as maize, has increased sharply. The total and irrigated maize area have had a sixfold and fourfold increase, respectively, since 1990. Maize area will expand further, and much of that expansion will take place in areas under other coarse cereals. Thus, additional water demand for increasing maize production could be marginal.
- Sugarcane area, with most of it under irrigation, has increased until 2000 and declined sharply since then. Even this area has a significant production surplus now. Whether this decline is a blip in the cropping pattern or a continuous trend is not exactly clear.
- Although area under cotton is declining, its production is gradually increasing. Adoption of high-yielding varieties, such as BT cotton, could be the main driver for yield growth. This trend is likely to continue into the future.

Annex Table 1. Land-use patterns at agroclimatic subregional level.

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Net sown area (1,000 ha)						Net irrigated area (1,000 ha)					
1970-1971	817	2,104	1,474	617	1,107	6,257	182	711	813	512	399	2,649
1974-1976	812	1,925	1,401	600	971	5,850	171	669	813	501	363	2,545
1979-1981	771	1,916	1,314	614	1,023	5,777	206	822	781	511	415	2,763
1984-1986	796	1,884	1,362	586	903	5,674	171	713	770	492	335	2,509
1989-1991	849	1,851	1,318	565	918	5,656	232	712	680	475	363	2,492
1994-1996	875	1,752	1,394	549	811	5,539	277	762	825	428	339	2,662
1999-2001	846	1,613	1,282	504	753	5,154	313	816	839	446	344	2,787
2004-2005	480	1,531	1,095	662	848	4,770	255	773	824	429	356	2,667
	Nonagricultural use area (1,000 ha)						Forest area (1,000 ha)					
1970-1971	153	404	395	192	332	1,499	480	746	418	14	178	1,992
1974-1976	146	476	417	180	378	1,629	475	724	412	18	181	1,980
1979-1981	113	509	467	188	417	1,726	494	714	412	19	186	2,024
1984-1986	114	521	502	191	419	1,780	496	745	426	19	184	2,069
1989-1991	118	534	523	195	420	1,824	535	777	431	19	193	2,153
1994-1996	126	556	551	200	431	1,898	543	764	431	19	191	2,146
1999-2001	134	616	601	162	440	1,987	538	772	431	10	185	2,134
2004-2005	188	654	637	166	449	2,132	536	762	431	10	185	2,120
	Current fallow area (1,000 ha)						Other than current fallow area (1,000 ha)					
1970-1971	101	370	160	25	253	913	44	172	128	22	186	557
1974-1976	131	647	279	48	342	1,452	39	136	111	30	236	557
1976-1981	192	727	362	41	369	1,707	36	98	97	20	200	457
1984-1986	140	606	314	59	347	1,482	63	241	114	30	340	794
1989-1991	89	640	328	50	238	1,357	44	220	139	54	401	868

1994-1996	74	637	215	39	230	1,207	30	269	197	69	457	1,030
1999-2001	92	610	266	20	213	1,209	36	317	235	46	492	1,132
2004-2005	124	411	285	20	70	917	44	415	260	60	566	1,349
	Permanent pasture and grazing land (1,000 ha)						Barren land (1,000 ha)					
1970-1971	27	76	75	6	36	230	161	178	284	32	111	819
1974-1976	26	65	58	5	27	189	149	152	233	36	63	663
1979-1981	26	48	47	6	24	159	140	139	208	39	52	588
1984-1986	26	38	44	6	25	145	132	137	183	39	56	556
1989-1991	26	31	38	5	19	124	113	129	167	36	59	510
1994-1996	27	30	41	5	18	125	110	118	156	39	60	490
1999-2001	41	90	100	23	115	377	110	119	143	36	62	476
2004-2005	46	102	96	22	122	396	110	147	142	36	64	506

Note: Hill and south regions have only 3% of NSA; 1% of NIA; 2% of nonagricultural use land, and less than 1% of the current fallow, other than current fallow, permanent pasture and grazing land, but 8% of forest area in 2005.

Annex Table 2. Total source-wise net irrigated area and as a percent of total NIA in agroclimatic subregions.

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Net canal irrigated area (1,000 ha)						Net canal irrigated area - % of total NIA					
1970-1971	25	267	98	474	23	907	14	38	12	93	6	34
1974-1976	20	254	104	461	22	875	12	38	13	92	6	34
1979-1981	25	282	96	470	22	907	12	34	12	92	5	33
1984-1986	24	249	78	448	20	830	14	35	10	91	6	33
1989-1991	25	265	62	417	22	801	11	37	9	88	6	32
1994-1996	26	264	63	384	21	770	9	35	8	90	6	29
1999-2001	30	265	69	425	21	822	10	32	8	95	6	29
2004-2005	15	245	60	399	27	762	6	32	7	93	7	29

	Net tank irrigated area (1,000 ha)						Net tank irrigated area - % of total NIA					
1970-1971	35	141	419	29	275	911	19	20	52	6	69	34
1974-1976	21	107	348	29	246	764	13	16	43	6	68	30
1979-1981	20	140	270	27	278	752	10	17	35	5	67	27
1984-1986	18	107	263	27	204	636	11	15	34	6	61	25
1989-1991	19	94	169	19	226	544	8	13	25	4	62	22
1994-1996	19	69	232	22	206	564	7	9	28	5	61	21
1999-2001	23	53	214	8	204	518	7	7	26	2	59	19
2004-2005	14	38	176	0	209	449	6	5	21	0	59	17
	Net dug-well irrigated area (1,000 ha)						Net dug-well irrigated area - % of total NIA					
1970-1971	120	286	264	8	99	778	66	40	33	2	25	29
1974-1976	125	300	281	8	94	808	73	45	35	2	26	32
1979-1981	157	390	296	7	113	963	76	47	38	1	27	35
1984-1986	126	344	324	8	109	912	74	48	42	2	32	36
1989-1991	183	332	318	10	114	959	79	47	47	2	31	38
1994-1996	222	399	383	8	110	1124	80	52	46	2	33	42
1999-2001	247	457	389	1	117	1214	79	56	46	0	34	44
2004-2005	197	419	377	1	116	1111	77	54	46	0	33	42
	Net tube-well irrigated area (1,000 ha)						Net tube-well irrigated area - % of total NIA					
1970-1971	0	6	14	0	0	20	0	1	2	0	0	1
1974-1976	0	3	60	1	0	65	0	0	7	0	0	3
1979-1981	0	4	105	4	1	114	0	1	13	1	0	4
1984-1986	0	6	95	8	1	110	0	1	12	2	0	4
1989-1991	2	15	126	28	2	173	1	2	19	6	0	7
1994-1996	7	24	144	12	1	188	2	3	17	3	0	7
1999-2001	11	31	163	11	2	218	3	4	19	3	1	8
2004-2005	24	68	207	29	4	332	9	9	25	7	1	12

	Net groundwater irrigated area (1,000 ha						Net groundwater irrigated area - % of total NIA					
1970-1971	120	292	278	8	99	798	66	41	34	2	25	30
1974-1976	125	303	341	10	94	873	73	45	42	2	26	34
1979-1981	157	395	401	10	113	1076	76	48	51	2	27	39
1984-1986	126	350	419	15	110	1022	74	49	54	3	33	41
1989-1991	185	347	445	38	115	1132	80	49	65	8	32	45
1994-1996	229	422	527	20	112	1312	83	55	64	5	33	49
1999-2001	258	488	552	13	119	1432	82	60	66	3	35	51
2004-2005	220	487	585	30	120	1443	86	63	71	7	34	54

Annex Table 3. Gross irrigated and cropped areas and irrigation and cropping intensity in agroclimatic subregions.

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Gross irrigated area (1,000 ha)						Irrigation intensity (%)					
1970-1971	233	902	1,126	663	482	3,472	128	127	138	130	121	131
1974-1976	214	841	1,051	603	398	3,158	126	126	130	120	110	124
1979-1981	278	1,034	1,030	673	504	3,570	136	126	131	132	121	129
1984-1986	242	827	1,078	619	389	3,203	141	116	140	126	116	127
1989-1991	298	849	936	547	415	3,096	128	119	138	115	114	124
1994-1996	392	896	1,089	555	384	3,363	144	118	132	130	113	126
1999-2001	403	842	1,022	554	360	3,226	129	103	122	124	105	116
2004-2005	332	821	912	428	456	2,983	131	106	111	100	128	112
	Gross cropped area (1,000 ha)						Cropping intensity (%)					
1970-1971	945	2,369	1,908	901	1,216	7,513	116	113	129	146	110	120
1974-1976	924	2,161	1,801	896	1,060	7,014	114	112	128	149	109	120
1979-1981	914	2,223	1,703	945	1,128	7,078	118	116	129	154	110	122
1984-1986	956	2,068	1,930	895	974	6,990	120	110	142	153	108	123

1989-1991	1,075	2,060	1,745	831	993	6,884	127	111	133	147	108	122
1994-1996	1,154	1,878	1,803	756	863	6,633	132	107	129	138	106	120
1999-2001	1,140	1,742	1,570	779	794	6,199	135	108	122	155	105	120
2004-2005	950	1,731	1,465	733	886	5,932	198	113	134	111	104	124
	Grain crop area (1,000 ha)						Irrigated grain crop area (1,000 ha)					
1970-1971	565	1,384	1,238	747	692	4,698	164	608	939	630	381	2,784
1974-1976	539	1,353	1,137	738	584	4,414	130	562	860	573	308	2,484
1979-1981	524	1,319	1,079	804	670	4,450	154	609	798	637	379	2,625
1984-1986	524	1,212	1,179	741	515	4,218	109	448	786	575	281	2,239
1989-1991	557	1,069	959	679	565	3,877	140	433	603	479	294	1,991
1994-1996	533	925	1,008	629	505	3,640	170	438	744	504	269	2,159
1999-2001	481	820	894	687	460	3,377	160	381	665	514	251	1,999
2004-2005	462	835	813	618	530	3,286	263	412	655	376	349	2,077
	Non-grain crop area (1,000 ha)						Irrigated no-grain crop area (1,000 ha)					
1970-1971	380	985	670	154	524	2,815	69	294	187	33	101	687
1974-1976	385	808	663	158	476	2,600	83	278	191	30	90	675
1979-1981	390	905	623	141	458	2,628	124	425	232	36	124	945
1984-1986	432	855	751	155	459	2,772	133	379	292	44	108	964
1989-1991	518	991	786	152	428	3,008	159	416	333	67	121	1105
1994-1996	622	953	795	127	358	2,993	222	457	346	51	115	1205
1999-2001	659	922	676	93	334	2,822	243	462	358	41	110	1226
2004-2005	488	896	652	115	355	2,646	69	409	257	51	107	906

Annex Table 4. Total crop and irrigated areas of rice, maize, other cereals and pulses in agroclimatic subregions.

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Paddy area (1,000 ha)						Paddy irrigated area (1,000 ha)					
1970-1971	122	479	940	653	405	2,665	122	457	865	625	325	2,456
1974-1976	104	446	850	614	331	2,397	89	422	782	568	254	2,164
1979-1981	116	514	790	657	445	2,573	116	475	741	634	347	2,362
1984-1986	87	391	815	579	327	2,243	82	373	747	572	258	2,073
1989-1991	102	387	620	493	387	2,034	101	375	573	477	279	1,847
1994-1996	127	398	748	517	353	2,181	127	391	727	503	261	2,044
1999-2001	123	344	660	528	331	2,018	123	328	639	514	241	1,874
2004-2005	216	296	644	466	350	1,994	216	217	627	376	324	1,782
	Maize area (1,000 ha)						Maize irrigated area (1,000 ha)					
1970-1971	1	10	0	3	0	14	1	9	0	2	0	11
1974-1976	1	14	1	5	0	20	1	12	0	4	0	16
1979-1981	1	17	2	2	0	23	0	14	1	1	0	17
1984-1986	2	19	1	2	1	25	1	12	0	2	0	16
1989-1991	2	30	1	1	1	34	1	15	0	1	0	18
1994-1996	3	39	0	0	5	47	2	23	0	0	1	27
1999-2001	6	56	1	0	17	81	2	30	1	0	4	37
2004-2005	17	146	8	1	23	196	7	61	5	1	7	80
	Other cereal area (1,000 ha)						Other cereal irrigated area (1,000 ha)					
1970-1971	324	714	226	5	209	1,480	41	143	74	3	56	317
1974-1976	326	729	233	7	205	1,502	41	129	77	2	54	303
1979-1981	284	621	210	4	158	1,279	38	119	56	1	32	247
1984-1986	282	638	239	5	126	1,290	26	62	39	1	22	150
1989-1991	258	459	189	3	85	994	37	43	30	1	15	126
1994-1996	182	326	132	1	58	699	41	25	16	0	6	88
1999-2001	144	289	105	0	56	595	35	23	24	0	5	88
2004-2005	151	272	57	0	58	541	40	22	24	0	3	88

	Pulses area (1,000 ha)						Pulses irrigated area (1,000 ha)					
1970-1971	117	182	72	86	78	539	1	6	1	0	5	13
1974-1976	108	164	54	113	48	493	1	4	2	0	2	9
1979-1981	123	165	77	141	66	574	1	7	3	0	3	14
1984-1986	152	165	124	155	62	660	4	7	9	0	3	24
1989-1991	195	193	148	181	93	815	11	18	10	6	6	52
1994-1996	221	162	128	111	89	713	32	42	17	15	8	114
1999-2001	207	130	128	158	57	684	21	9	19	2	2	54
2004-2005	78	120	104	152	100	554	0	6	15	3	2	26

Annex Table 5. Total crop and irrigated areas of rice, maize, other cereals and pulses in agroclimatic subregions.

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Oilseed area (1,000 ha)						Oilseed irrigated area (1,000 ha)					
1970-1971	192	426	487	70	90	1280	11	56	116	15	9	206
1974-1976	196	325	468	78	70	1157	13	45	97	12	7	173
1979-1981	189	369	435	83	71	1165	20	116	123	15	10	284
1984-1986	233	371	526	93	88	1330	22	86	148	18	11	286
1989-1991	242	426	516	99	103	1405	32	104	155	23	13	328
1994-1996	314	411	481	75	88	1390	48	103	158	11	8	328
1999-2001	259	377	340	55	82	1136	59	78	129	8	6	279
2004-2005	163	373	339	57	89	1045	5	55	95	14	16	186
	Fruits/vegetable area (1,000 ha)						Fruits/vegetable irrigated area (1,000 ha)					
1970-1971	38	86	41	17	24	243	24	41	8	6	16	98
1974-1976	47	94	47	13	26	257	26	43	13	6	17	108
1979-1981	54	115	53	16	28	296	36	65	19	6	20	148
1984-1986	55	111	60	16	31	301	33	59	23	6	19	143
1989-1991	86	129	74	16	32	363	37	66	33	6	24	171
1994-1996	105	149	79	14	39	413	49	96	41	7	32	230

1999-2001	144	206	95	12	51	534	69	113	41	6	38	275
2004-2005	142	207	119	13	54	562	16	100	44	6	44	216
	Sugarcane area (1,000 ha)						Sugarcane area (1,000 ha)					
1970-1971	14	44	47	6	5	116	14	44	47	6	5	115
1974-1976	24	56	59	7	6	152	22	53	59	7	6	147
1979-1981	26	73	65	11	8	183	26	71	61	8	7	173
1984-1986	31	64	90	11	8	203	26	63	76	11	6	182
1989-1991	26	70	103	25	13	238	26	69	100	23	13	230
1994-1996	40	89	137	23	15	305	24	89	87	8	8	216
1999-2001	44	98	141	18	18	320	41	98	140	17	14	310
2004-2005	34	79	128	21	24	289	18	69	80	16	21	203
	Cotton area (1,000 ha)						Cotton irrigated area (1,000 ha)					
1970-1971	21	141	4	1	150	317	8	74	1	0	20	104
1974-1976	16	112	7	1	127	262	7	61	4	0	15	87
1979-1981	26	94	8	2	120	248	18	52	6	1	34	112
1984-1986	23	83	16	5	111	239	18	53	12	4	20	107
1989-1991	31	79	15	5	126	255	18	37	10	5	23	92
1994-1996	45	98	29	5	81	257	21	36	9	5	16	86
1999-2001	31	74	16	5	45	170	17	22	6	5	12	61
2004-2005	28	39	13	8	33	120	9	15	4	7	9	43
	Other non-grain crop area (1,000 ha)						Other non-grain crop irrigated area (1,000 ha)					
1970-1971	114	287	92	60	256	859	13	79	14	6	51	164
1974-1976	102	221	83	59	247	772	16	76	19	5	44	160
1979-1981	95	253	62	30	232	736	25	121	23	5	53	228
1984-1986	89	227	59	29	222	699	34	117	34	5	51	246
1989-1991	133	289	77	8	154	747	46	141	35	10	47	283
1994-1996	119	206	69	10	135	629	81	133	52	20	52	345
1999-2001	180	168	83	3	139	662	58	151	42	5	39	302
2004-2005	121	198	52	17	155	631	21	170	34	9	18	257

Annex Table 6. Crop yields of major crops in agroclimatic subregions (tons/ha).

Year	Agroclimatic subregions						Agroclimatic subregions					
	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu	North	Central	South-east coastal	Delta	North-east coastal	Tamil Nadu
	Paddy						Sorghum					
1970-1971	2.09	2.20	1.95	1.84	1.65	1.93	0.63	0.64	0.93	1.03	1.02	0.69
1974-1976	2.19	2.10	2.06	1.68	1.58	1.91	0.59	0.65	1.21	0.81	0.96	0.71
1979-1981	2.07	2.24	2.10	2.21	1.85	2.12	0.94	0.76	1.04	1.86	1.58	0.87
1984-1986	2.74	2.78	2.54	2.45	1.87	2.46	1.25	0.76	1.33	0.95	1.29	0.93
1989-1991	3.25	3.53	3.22	3.16	2.16	3.07	1.06	1.00	1.10	1.00	1.56	1.05
1994-1996	3.36	3.27	2.94	2.64	2.73	2.94	1.35	0.82	1.19	0.88	1.66	1.00
1999-2001	4.02	3.96	3.51	2.18	2.11	3.06	1.37	0.82	1.14		0.98	0.93
2004-2005	1.28	3.24	2.83	1.63	2.23	2.35	1.03	0.62	1.13		0.87	0.74
	Millet						Pulses					
1970-1971	0.85	0.69	0.96		0.73	0.79	0.14	0.27	0.23	0.18	0.18	0.21
1974-1976	0.91	0.92	1.34		0.69	0.96	0.23	0.28	0.37	0.29	0.26	0.28
1979-1981	1.19	0.99	1.28		1.05	1.12	0.33	0.32	0.35	0.20	0.27	0.29
1984-1986	1.29	1.01	1.46		1.10	1.24	0.48	0.46	0.43	0.36	0.34	0.42
1989-1991	1.87	1.11	1.36		1.38	1.44	0.44	0.37	0.47	0.42	0.47	0.43
1994-1996	1.99	0.96	1.30		1.47	1.48	0.46	0.35	0.42	0.32	0.29	0.39
1999-2001	1.98	1.02	1.66		1.67	1.68	0.53	0.39	0.43	0.21	0.74	0.43
2004-2005	1.34	1.02	1.39		1.54	1.33	0.38	0.37	0.42	0.14	0.58	0.35
	Oilseed						Groundnut					
1970-1971	0.97	0.91	0.99	0.62	0.67	0.91	1.11	1.07	1.07	0.92	0.97	1.06
1974-1976	0.73	0.77	1.05	0.66	0.49	0.84	0.83	0.91	1.12	0.99	0.82	0.99
1979-1981	0.83	0.97	0.93	0.65	0.55	0.87	1.20	1.31	1.14	1.22	1.17	1.21
1984-1986	0.95	0.92	1.03	0.72	0.68	0.93	1.09	1.11	1.21	1.02	0.99	1.14
1989-1991	1.10	0.90	1.18	0.65	0.58	0.98	1.30	1.21	1.29	1.28	0.96	1.25
1994-1996	1.32	1.03	1.50	0.67	0.60	1.20	1.64	1.40	1.66	1.47	1.33	1.57
1999-2001	1.36	1.06	1.70	0.40	0.63	1.24	1.80	1.39	1.98	1.69	1.59	1.72
2004-2005	0.99	1.05	1.55	0.51	0.65	1.12	1.37	1.43	1.81	2.10	1.71	1.60

	Sugarcane						Cotton					
1970-1971	78	105	79	84	91	90	0.34	0.32	0.34	0.43	0.38	0.35
1974-1976	92	98	106	101	89	100	0.23	0.31	0.28	0.37	0.43	0.36
1979-1981	126	89	100	73	68	96	0.27	0.30	0.32	0.35	0.81	0.54
1984-1986	102	111	103	92	99	105	0.41	0.40	0.45	0.48	0.96	0.68
1989-1991	111	109	98	114	111	105	0.29	0.31	0.39	0.37	1.32	0.82
1994-1996	105	118	100	87	91	104	0.30	0.27	0.29	0.30	0.72	0.42
1999-2001	102	119	97	82	95	103	1.87	1.82	1.81	1.36	1.48	1.73
2004-2005	95	106	102	79	49	96	b1.77	1.39	1.73	1.20	1.29	1.47

Sources of contribution to growth in crop production.

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