To Quantify the Impact of Energy Crisis on Irrigation

Dr. P. Paramasivam
Professor of Agricultural Economics

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Government of Tamil Nadu
Chennai

Department of Agricultural Economics
Centre for Agricultural and Rural Development Studies
Tamil Nadu Agricultural University
Coimbatore – 641 003

Executive summary

This study seeks to address the electricity-well irrigation related issues in the context of their growing usage and scarcity in the agricultural sector of Tamil Nadu. Existing studies indicate temporal and spatial changes in pattern/sources of irrigation and crop diversity across districts. It is necessary to examine how these two are related with growing groundwater irrigation closely linked to availability of electricity for pumping water. Additionally it is also interest to relate these trends to rainfall to understand their combined impact on production in times of water scarcity and to explore options for stabilizing the same at such scarcity periods.

In recent years growth rate of agriculture and allied sectors has slipped down from 7.1 per cent in 2011-12 to 1.1 per cent in 2012-13. While deficient monsoons and erratic rainfall leading to overall drought might have been a reason for the recent fail in agricultural production the continuing trend is a reason for concern and an indicator for some potential structural issues of the sector that need to be understood for corrective action.

During 2012-13, winter and summer rainfall were deficient by 70% and 33% respectively due to 24% deficiency in rainfall during South West monsoon. While 370.50 mm cumulative rainfall was received during the North East Monsoon against the normal rainfall of 440.40 mm with 16% deviation, which is normal as per IMDA parlance, its distribution during 2012 was highly skewed with most of this received in a short spell towards the end of October, 2012.

Thus, a combination of inadequate local water sources, decline in surface water availability due to in situ usage by upper irrigation where the sources originate, growing usage in all sectors of the economy have led to growing gaps between demand for and supply of water in the State. With surface water sources proving inadequate to meet the needs, groundwater extraction has gained momentum in almost all user sectors in the state, especially in agricultural sector. Out of the total net irrigated area of 2.88 million hectares, canal source accounted for about 0.84 million hectares, wells covered about 1.37 million hectares. The areas irrigated by canals and tanks have been continuously and consistently declining in the State over the decades.

Dug wells increased from 7.9 lakhs to 18 lakhs and shallow bore wells from a few thousands to 1.35 lakhs during this period. With increasing well numbers a significant proportion of them were also being abandoned. Abandoned wells rose from 58,308 during 1960-61 to as high as 1,20,837 during last decades has increased the probability of well failures and premature well abandonment. It has led to declining water table and deeper tube wells associated with increases in investment and energy equipments.

Extraction of groundwater demands energy and thus electricity demand for groundwater pumping is also on the rise. Impact of this growing dependence has been felt in the agricultural sector of the state in the recent years. Total number of energized wells during 1950-51 was merely 0.14 lakhs, where as it rose to 18.33 lakhs 2000s. Availability of power is one of the crucial inputs necessary for sustained growth of any economy.

Over the last few years, Tamil Nadu has been facing massive power deficits. Domestic consumers along with agricultural and industrial (LT) category of consumers account for about 85 per cent of the total electricity consumption. However a shift in the

pattern of consumption of power is visible. Proportion of domestic consumption has increased from 25.1 to 26.35 per cent during 2003-04 to 2010-11.

When monsoons fail, they introduce a general uncertainty in water availability for irrigation in the State. Since a significant proportion of canal water is to be received from upper riparian States, opening of dams for irrigation is delayed. Declining water levels in project areas impact hydel power generation. Irrigation tanks dry up. All these factors increase the dependence on ground water which also coincides with power shortages and groundwater irrigation suffers both for lack of adequate groundwater and pumping energy. In many parts of the State, where groundwater irrigation has already become the dominant source of irrigation, crop production suffers and often crops fail.

Many studies have been conducted over years regarding cropping pattern, sources of irrigation and patterns of irrigation in the State in isolated pattern. As noted earlier, significant changes have been observed in temporal and geographical distribution of crops grown. Many minor millets have been replaced by water intensive cash, food and commercial crops. Crops like maize have been gaining in area at the cost of crops like cotton. Similarly there have been significant temporal and geographical changes in terms of sources and extent of irrigation across the districts of the State. More and more districts have come under groundwater over exploited Zones. Not many studies are available that seek to analyse the changes in the cropping pattern in the light of changes in the pattern and sources of irrigation across the districts. This study therefore, aims to relate cropping pattern changes, to changes in sources of irrigation across the districts. Additionally, the changes in irrigation sources are to be related to external factors like rainfall and their overall implications for groundwater dependence. Crop yield levels will be correlated with these trends and availability seasonal power for groundwater irrigation. The objectives of the study will be

i) To assess the temporal and geographical changes in pattern and sources of irrigation and their impact on cropping pattern.

ii) To assess the factors contributing for increasing groundwater dependence and pattern of electricity consumption for groundwater irrigation.

iii) To assess the impact of groundwater on crop production in the context of rainfall and power availability uncertainties.

iv) To review results/studies and suggest policy options to stabilize crop production under power shortages for groundwater irrigation

Methodology

This study comprises of two parts; first part was to estimate share of different sources of irrigated area (surface and well irrigation) to net irrigated area and to estimate the trend of electricity consumption through number of pump sets electrified in the regions For conducting second part of primary survey analysis districts were selected based on highest share of number of pump sets electrified and well area to net irrigated.

Thiruvannamalai, Coimbatore and Erode districts were for conducting field survey. Blocks were selected based on highest well area and number of pump sets electrified during the study year (G return, 2010-11) followed by villages based on the same criteria. Random sampling method was adopted to select 10 farmers in each village. With two villages from each block and two blocks from each district the district sample size was 40 farmers. The study was conducted in three districts with a total sample size of 120 farmers.

Data on sources of irrigation and area under crops irrigated is available for districts, were estimated as

$a_{ij=} [A_i / \times A_i] [S_j / \times S_j]$

Where, A_i includes major irrigated crops such as paddy, sugarcane, coconut, total cereals, total food grains, total fruits and vegetables, total food crops, total oil seeds and total non-food crops. $S_j$constitute net irrigated area of both well and surface area to gross irrigated area for the temporal period of 1991-2011 at districts level. Hence, a_{ij}results were converted to percentage.

Net irrigated area by different source of well, electricity consumed by agricultural sector and area under different food crops was analysed using compound growth rate.

Factors influencing well area

The present study used the following empirical model of multiple linear regression equation given below:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it}$$

Where,
Y = Well irrigated area (ha)
X_1 =Rainfall (mm)
X_2 = Pump sets (no.)
X_3 = Surface irrigated area (ha)
X_4 = Time

Impact of Groundwater over-draft and power cut on farm income

Groundwater over draft increased cost of well deepening and reduced extraction rate. The following functional analysis based on factors was estimated

$$Y= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$$

Where

Y = farm income (Rs)
X_1 =Total land holding of household (ha)
X_2 = Education of household head
X_3 = Family members (No)
X_4 = Depth of well (feet)
X_5 = Square of depth (feet)
X_6 = Per cent of area under irrigation
X_7 = Power cut per day

Cost of Groundwater over-draft and power cut

In this study, direct and indirect costs associated with groundwater over-draft and power cut have been estimated as follows.

Cost of groundwater over-draft and pump sets = Direct cost + Indirect cost
where

Direct cost = Sunk cost + Replacement cost; and
Indirect cost = Net losses due to change in cropping pattern + Decline in net sown area under irrigation.

Conclusions

The main objectives are to assess the temporal and geographical changes in pattern and sources of irrigation and their impact on cropping pattern; to assess the factors contributing for increasing groundwater dependence and pattern of electricity consumption for groundwater irrigation; to assess the impact of groundwater on crop production in the context of rainfall and power availability uncertainties. It was carried out using both secondary and primary data.

Changes in cropping pattern are discernable over the past decades. Broadly area under food grains declined in Tamil Nadu for the past two decades while area under sugarcane, fruits and vegetables and coconut significantly increased. Relative share of agricultural power consumption to total power consumptionhas declined. Relative area shares of Coconut, fruits and vegetables increased in almost all districts while declining trend was noticed in major water intensive crop paddy in Vellore, Dharmapuri, Coimbatore, Salem, Erode, Thanjavur, Madurai, Dindigul, Ramanathapuram, Sivagangai and Tuticorin districts. Similarly sugarcane area share declined in Kancheepuram, Coimbatore, Thanjavur, Madurai, Dindigul and Virudhunagar districts. Total food crops shares increased in Kancheepuram, Cuddalore, Vellore, Thiruvannamalai, Salem, Erode, Tiruchirappalli, Pudukottai, Madurai, Thirunelveli and Tuticorin whereas total non-food crops increased in Vellore, Salem, Erode, Tiruchirappalli, Pudukottai, Madurai, Thirunelveli, Dharmapuri, Sivagangai and Virudhunagar districts. There was increase in absolute power consumption in all districts and State as a whole even while its relative share exhibited a negative trend. Overall, paddy area declined while sugarcane, coconut, fruits and vegetables area increased in the State.

Area under paddy irrigated, though accounts for the single largest share, has been declining in the State over the decades at about 14,800 hectares per year. This decline has been more or less compensated by the increase in irrigated area under sugarcane, groundnut and coconut. Area under traditionally irrigated crops like cholam, cumbu and ragi has been declining in the same period. These have implications, besides changes in food habits, decline in livestock and fodder needs, for the sources of irrigation as well. The trends also indicate that inspite of concerted efforts improvements in area under pulses and oilseeds (except coconut) could not take off to any significant extent.

Number of wells has been growing at an annual compound growth rate of 1.6 per cent for the past four decades in Tamil Nadu. The rate of growth in almost all the districts except hilly and delta regions is almost equivalent to that of the State. Increase in the numbers of wells has also been translated into corresponding increase in the area irrigated by wells and tube wells. Other than paddy most of the irrigated crops are predominantly dependent on groundwater irrigation through wells with energized pump sets.

However, excessive dependence on wells, in turn results in the reduction in well yield, drying up of shallow wells, deterioration of water quality, sea water intrusion into the coastal aquifers, increased energy required to lift water from greater depth and its consequent high cost, which becomes uneconomical to poor farmers to continue agriculture. Further many of the agricultural fertile lands have become barren in coastal area like Minjur. In many blocks of the State water resources have been over exploited. With more and more wells being dug and deepened to extract groundwater, increasingly many wells go into disuse since they dry up. The annual compound rate of well numbers being abandoned at the State level has been growing at a very high rate of 2.5 per cent. This indicates that growing dependence on well irrigation has been leading to severe externalities in the form of well abandonment. Well abandonment is closely associated with declining water tables and newer wells need to be dug deeper with increased capital outlay and pumping costs besides the capital lost through the wells abandoned.

Growth rate in well area increased also aidedby free electricity and absolute increase in energy consumption. Surface irrigated area and paddy area had negative trend over the past two decades due to reduced number of rainy days during different monsoon periods and declining groundwater availabilities in an aquifers. From regression analysis, it was observed that rainfall and number of pump sets had positive significant impacts onarea irrigated by wells while surface irrigated area hada negativeimpact.

Majority of farm households depend on farm income and frequent power cut and declining availability of groundwater during deficit rainfall periods adversely affect net farm income. Cost of groundwater over-draft and power cut increases both direct and indirect costs for well deepening and widening. Mean groundwater availability, running hours per day and area irrigated per hectare was high during North East Monsoon compared to other seasons.

Farm survey indicated that farmers experience yield losses varying from about 5 per cent for paddy to more than 50 per cent for coconut during drought periods coupled with scarcity of electricity for pumping ground water. Scarcity of energy is a major issue with respect to canal regions were water intensive crops like paddy banana, sugarcane, and turmeric are the major crops. In such areas groundwater still can supplement canal water during occasional droughts. However since drought periods generally coincide with reduced hydal energy generation dud to low storage in reservoirs energy availability becomes the major limiting factor. Regions normally dependent on groundwater suffer more due to water scarcity during periods of drought. Wells become defunct, deeper and denser with escalating demand for energy even to extract the same quantum of water. In such areas, coconut, being a perennial irrigated crop is worst affected. Other crops also suffer yield losses. Most importantly people try to switch to less water intensive fodder crops or reduce cultivated area to few vegetable crops where market access is available.

In order to manage groundwater table, efforts should be taken for increased recharge through works likedesilting and renovation of existing tanks, watershed development programme at grass root levels with people participation and rainwater harvesting. Electricity is debated to be one of the key components for groundwater over-draft. Appropriate electricity usage policies for agriculture sector might be considered for implementation not only to manage ground water but also to improve the efficiency of power consumed in the sector. Already norms and guidelines have been framed for managing wells and groundwater extraction in the state and they need effective implementation. Similarly the efficiency of pump sets used for groundwater extraction needs to be improved.

Tamil Naduenergy deficit of only around 1% in 2003-04 has been increasing rapidly, especially in the last five years due to the absence of increase in availability of power compared to states such as Maharashtra, Gujarat and Andhra Pradesh which added capacity to increase the availability of power both by increasing own capacity and by encouraging private investment. Moreover most of the added capacity in Tamil Nadu was in the wind energy sector which is seasonal and its production fluctuating.

These factors that have contributed for power shortages have affected all sectors of the economy by way of load shedding, power cuts and related restrictions. Agriculture sector has also been affected by overall shortage of power. One more aspect to be considered is the non-availability of metered data to accuratley measure electricity consumption in the sector. In such a situation agriculotural sector share is computed as a residual in total power consumption of the state after deducting consumption by all other sectors. The fact that systematic measurements on T&D losses in various sectors are not available and that its share has been recorded almost constant at around 19 percent leads one to suspect that it may be an under estimate in the absence of any major upgrades to the T&D system. To that extent, the recorded electricity consumption in the agricultural sector would be an over estimate.

Even assuming agricultural power consumption data is accurate, growth in the number of pump sets over years, and declining water table indicate the need for more energy to maintain per pump set energy consumption and also to pump the same quantum of water.

Alternative energy sources for agriculture

Operating pumpsets for groundwater irrigation is the major source of electricity demand from agricultural sector. With more than 50 per cent of area being well irrigated shortages of power supply to this sector has an adverse impact on agricultural production. While using fossil fuels for operating pumpsets or generators is not cost effective, renewable sources of energy like wind and solar energy could help to mitigate the impacts of power shortage. In fact government of Tamil Nadu has initiated measures to promote solar pumpsets.

The Tamil Nadu Government has started distributing solar powered agriculture pump sets that can be used in bore wells, deep bore wells and open wells at subsidised rates to farmers in the year 2013-14. Agriculture Department is expected to distribute about 2,000 pump sets of 5hp fitted with solar tracking device. State Government will provide 80 per cent subsidy, about Rs. 4 lakh per unit. TheRs. 100-crore programme is expected to be linked to support the micro-irrigation facilities for various crops. Small and marginal farmers get 100 per cent subsidy for setting up drip irrigation and other micro irrigation facilities. Other farmers get a 75 per cent subsidy.The objective is to address the challenge of water shortage and power constraints.The Tamil Nadu Energy Development Agency is to take care of the operational details of the scheme.

Policy options

- It needs to be recognized that surface and groundwater are complementary sources and that groundwater is dependent on surface flows and is essentially suited for stabilizing the water delivery to whatever sector requiring it. The objective is clearly to harness as much surface flows as possible through tanks and reservoirs with minimal delivery losses and to the extent possible use the surface water to effectively meet the sectoral demands. A part of the flow may be planned for groundwater recharge to be used as a stabilization reserve. There seems to be no point in looking at groundwater as an independent source of water. Though this appears a simple proposition it may be highly demanding in terms of technical assessments, organizational changes and institutional arrangements for even elementary functionality.

- In future as the stress on the water delivery system will be more pronounced due to growing demands from all user sectors including agriculture, management wouldhe critical on both supply and demand sides, especially on the demand side given that the available resources potential of the State are limited

- On the supply side avoiding delivery losses along the delivery systems, recycling of non consumptive water usage through adequate treatment and optimizing storage reservoirs could help to a limited extent both in canal and tank systems. However, this has to be approached after adequate analysis since already heavy investments have been made in the form of system modernization and the returns real social returns to such investments and cost recovery have not yet been properly assessed and understood.

- On the demand side biggest gains have to come from rationalising water use in the agricultural sector. This might involve reorganizing the cropping, pattern, substituting high water intensive crops with economically comparable less water intensive crops of lesser duration. For instance paddy, to the extent possible may be substituted with less water intensive high value commercial crops.
- Groundwater utilization in the State, now largely unregulated, needs to be rationalized by taking into consideration the potential and actual rechargeappropriate local assessments.
- Besides agriculture, all other sectors using water from the basin shall be made accountable for their water use activities.
- Agriculture sector has also been affected by overall shortage of power. There is need to generate metered data to accurately measure electricity consumption in the sector. Present approach of computing agricultural power consumption as a residual in the absence of systematic measurements on T&D losses in various sectors may not give correct picture of electricity consumption in the agricultural sector.
- Even assuming agricultural power consumption data is accurate, growth in the number of pump sets over years, and declining water table indicate the need for more energy to maintain per pump set energy consumption and also to pump the same quantum of water. Pump set efficiency needs to be improved.
- Use of alternate renewable sources of energy like solar and wind energy needs to be promoted. Solar energy offers much hope with technological advancements and continuous availability of sun light in Tamil Nadu for most part of the year. Present efforts of providing solar pumpsets with subsidies and propaganda may be linked to more agricultural development oriented programmes like water shed development, horticultural development and precision farming.

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Introduction

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Though Tamil Nadu is one among the better placed States in the India in terms of its overall economic performance, the same cannot be said of its agricultural sector that still accounts for a major proportion of rural employment and livelihood. Net State Domestic Product (NSDP) from agricultural sector at constant prices recorded only a meager growth rate in the last 10 years. Over the last decade the Gross State and Net State Domestic Products (GSDP and NSDP) at constant prices have grown by 70 per cent while that of agricultural and allied activities have recorded a growth of only about 6 to 7 percent. Annual compound growth rates for the overall State GSDP and NSDP at constant prices workout to about 6.7 per while the same for agricultural and allied activities is only about 1.5 per cent. Since the relative growth is retarded, the share of agriculture in the NSDP at current prices has declined from 15.93 percent to 11.18 per cent during the same period.

In recent years growth rate of agriculture and allied sectors has slipped down from 7.1 per cent in 2011-12 to 1.1 per cent in 2012-13. While deficient monsoons and erratic rainfall leading to overall drought might have been a reason for the recent fail in agricultural production the continuing trend is a reason for concern and an indicator for some potential structural issues of the sector that need to be understood for corrective action.

Agriculture, unlike the manufacturing and industrial sectors is nature dependent. Apart from land, water and inputs especially nutrients are crucial factors in determining agricultural production. Among them, water assumes significance because it is the factor that determines the land use pattern and intensity, cropping pattern and technology adoption as well as nutrient management. Unfortunately the State is not adequately endowed with its own natural water sources. Although the Government, with a serious concern to place the agriculture sector on a high growth trajectory, resorted to several measures like enrichment of soil fertility, whole village concept for paddy and pulses, intensification of millets and red gram (through transplantation), sustainable sugarcane initiatives, precision farming, micro irrigation, group extension, cluster approach, integrated farming, solar energized pumpsets under farm mechanization, IT based farm level interventions etc, the efforts were marred by various extraneous factors such as Nilam cyclone, poor storage position in all major reservoirs, failure of South West as well as North East Monsoon, non-release of Cauvery water by Karnataka etc., which resulted in lesser coverage of area in major crops as well as damage to the standing crops.

During 2012-13, winter and summer rainfall were deficient by 70% and 33% respectively due to 24% deficiency in rainfall during South West monsoon. While 370.50 mm cumulative rainfall was received during the North East Monsoon against the normal rainfall of 440.40 mm with 16% deviation, which is normal as per IMDA parlance, its distribution during 2012 was highly skewed with most of this received in a short spell towards the end of October, 2012.

One million cubic meter (m.cu.m) of water supported about 1813 in Tamil Nadu compared to about 1100 persons per m. cu. M for all India in 2000. With 7 per cent of the population the state is having only about 3 per cent of Countryǿs water resources. With a total geographical area of 130069 square km under 17 river basins and an average annual rainfall of 946 mm the state receives about 123.20 km^3 of rainwater (12.32)per year. Assuming a run off co- efficient between 0.0 and 0.55, the normal annual surface flows work out to 60.71 km3 or 6.07 MHM of which the utilizable runoff is about 24.86km3 or 2.486 MHM. The utilizable flow is low due to i) lack of storage space, ii) unsuitable distribution of supply in time and space, iii) practical difficulties in formation of reservoirs and iv) evaporation and other losses from storage. Besides this there is also transfer/import of surface water from other states like Kerala, Karnataka and Andhra Pradesh. Estimates by the working Group on the estimation of Groundwater Resources had indicated that the utilizable groundwater recharge will be about 2.24 MHM. Thus, in any case the total water potential of Tamil Nadu would be about 4.74 MHM i.e., 2.50 MHM from surface water and 2.24 MHM from groundwater sources.

Domestic and industrial uses of water in the state at present claim a share about 15 per cent in the total resources and this share is likely to be about 2 per cent in the year 2025 AD with increased industrialization, urbanization and growing needs of rural areas for improved facilities for drinking water. The National Commission on Agriculture has indicated that although the percentage utilization for purposes other than irrigation is low at present, this is expected to rise appreciably in the future with increase in industrialization and power generation through thermal and nuclear plants. By 2025 AD the requirement of fresh water for non-irrigation purposes may be around 27 per cent of the available freshwater. Thus, the total demand for non-agricultural purposes in the state will be about 1.65 MHM.

Projected area under irrigated crops for 2025 AD will be 4.47 million hectares and the corresponding water requirements will be 5.21 MHM, which is higher than the supply available for crops is about 2.12 MHM (44.72 per cent). The gap based on National Commission on Agricultureǿs estimate of 0.80 HM per hectare is 0.48 MHM (10.12 per cent). It is possible that allocation of water for agriculture will be reduced to 65 per cent in another 10 to 15 years.

Thus, a combination of inadequate local water sources, decline in surface water availability due to in situ usage by upper irrigation where the sources originate, growing usage in all sectors of the economy have led to growing gaps between demand for and supply of water in the State. With surface water sources proving inadequate to meet the needs, groundwater extraction has gained momentum in almost all user sectors in the state, especially in agricultural sector. Out of the total net irrigated area of 2.88 million hectares, canal source accounted for about 0.84 million hectares, wells covered about 1.37 million hectares. The areas irrigated by canals and tanks have been continuously and consistently declining in the State over the decades.

The combined area irrigated by canals and tanks had declined from a peak of about 7 per cent in the fifties and early sixties to about 50 per cent in mid-nineties. This decline was more or less compensable by the significant growth in the area irrigated by wells that increased from about 2 per cent shown a phenomenal rise between fifties and recent decades. Besides meeting gap, groundwater use seems to have additional justifications. According to some reports, groundwater irrigation already accounts for 75-80 per cent of the value of irrigated production in India. Groundwater not only accounts for more than 50 per cent of the total area under irrigation, but is also around 100 per cent more efficient than canal water in terms of productivity per hectare. This is indeed the reason why it is in such a great demands by the farmers who can develop it quickly and easily with their own resources, assited by institutional credit, wherever necessary. Private investment in groundwater development, supported by institutional credit and government subsidies, has increased phenomenally during the last two decades. Over 95 per cent of the area served by groundwater in India is commanded by privately owned wells.

Dug wells increased from 7.9 lakhs to 18 lakhs and shallow bore wells from a few thousands to 1.35 lakhs during this period. With increasing well numbers a significant proportion of them were also being abandoned. Abandoned wells rose from 58,308 during 1960-61 to as high as 1,20,837 during last decades has increased the probability of well failures and premature well abandonment. It has led to declining water table and deeper tube wells associated with increases in investment and energy equipments.

Extraction of groundwater demands energy and thus electricity demand for groundwater pumping is also on the rise. Impact of this growing dependence has been felt in the agricultural sector of the state in the recent years. Total number of energized wells during 1950-51 was merely 0.14 lakhs, where as it rose to 18.33 lakhs 2000s. Availability of power is one of the crucial inputs necessary for sustained growth of any economy.

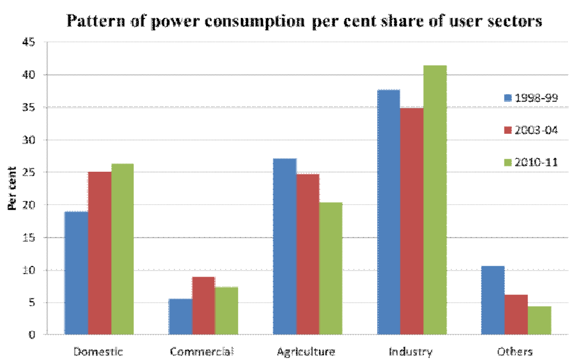
Over the last few years, Tamil Nadu has been facing massive power deficits. According to the CEA, the state was expected to have a power deficit of around 18% in 2010-11. On an average, 3-4 hours of power cuts are being experienced by consumers in the state. The installed capacity of conventional energy sources of Tamil Nadu Generation and Distribution Corporation Limited is 10515.34 MW as on 31.03.2013 which includes TANGEDCOȏs Hydro (2237.4 MW), Thermal (2970 MW), Gas Stations (515.88 MW), share from Central Generating Stations (3520 MW), Private Power Projects (1154.16 MW), External Assistance (50 MW) and others (67.9 MW). The installed capacity of non-conventional energy sources as on 31.03.2013 (infirm power) is 7999.02 MW which includes wind generation (7145.22 MW), solar (17 MW), Biomass (177.4 MW), Co-generation plants (659.40 MW). Tamil Nadu accounts for 39% of wind power generation in India. The present demand of power in the state is around 12,000MW. The average availability of power from the existing conventional and non-c0nventional energy sources is about 8000 MW. At present this deficit is managed through power purchase and Restriction and Control measures. TANGEDCO is taking several steps to bridge the gap between demand and supply to provide uninterrupted power supply to the consumers.

Domestic consumers along with agricultural and industrial (LT) category of consumers account for about 85 per cent of the total electricity consumption. However a shift in the pattern of consumption of power is visible. Proportion of domestic consumption has increasedfrom 25.1to 26.35 per cent during 2003-04 to 2010-11.

Table 1.1 Pattern of power consumption per cent share of user sectors

Sl. No.	Sector	1998-99	2003-04	2010-11
1.	Domestic	19.0	25.1	26.35
2.	Commercial	5.6	9.0	7.41
3.	Agriculture	27.1	24.8	20.40
4.	Industry	37.7	34.9	41.39
5.	Others	10.6	6.2	4.45
	Total Sales (mu)	16117	33997	61897

Source: Statistics at a Glance 2010-11 TNEB, Chennai 600 002.



Industrial sector power consumption rose from 34.9 per cent in 2003-04 to 41.39 per cent in 2010-11. There has been a gradual reduction in the share of agricultural power consumption since 2000-0. Its share declined to 20.40 percent in 2010-11 form 24.8 per cent in 2003-04.

Considering month wise power consumption, summer months between April and June had an average increase of 4.6 per cent in demand. Against this, the availability had an increase of 1.5 per cent. Power deficit at 3.31 per cent for instance, in May 2008 increased gradually to reach 13.14 per cent in October 2008. Likewise, the highest peak demand of 8894 MU was met during September 2008. These demands coincide with the cropping seasons and hence have a greater significance for agricultural power consumption, especially irrigation.

When monsoons fail, they introduce a general uncertainty in water availability for irrigation in the State. Since a significant proportion of canal water is to be received from upper riparian States, opening of dams for irrigation is delayed. Declining water levels in project areas impact hydel power generation. Irrigation tanks dry up. All these factors increase the dependence on ground water which also coincides with power shortages and groundwater irrigation suffers both for lack of adequate groundwater and pumping energy. In many parts of the State, where groundwater irrigation has already become the dominant source of irrigation, crop production suffers and often crops fail.

Many studies have been conducted over years regarding cropping pattern, sources of irrigation and patterns of irrigation in the State in isolated pattern. As noted earlier, significant changes have been observed in temporal and geographical distribution of crops grown. Many minor millets have been replaced by water intensive cash, food and commercial crops. Crops like maize have been gaining in area at the cost of crops like cotton. Similarly there have been significant temporal and geographical changes in terms of sources and extent of irrigation across the districts of the State. More and more districts have come under groundwater over exploited Zones. Not many studies are available that seek to analyse the changes in the cropping pattern in the light of changes in the pattern and sources of irrigation across the districts. This study therefore, aims to relate cropping pattern changes, to changes in sources of irrigation across the districts. Additionally, the changes in irrigation sources are to be related to external factors like rainfall and their overall implications for groundwater dependence. Crop yield levels will be correlated with these trends and availability seasonal power for groundwater irrigation. The objectives of the study will be

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Background of the study

The share of irrigated and rainfed area to total cultivated area in Tamil Nadu is about 48 and 52 per cent respectively (Season and Crop Report, 2012).Well irrigated areaincreased significantly from 1950s to 1980s as also the well numbers. But share of groundwater irrigated area started stagnating since early 1980s despite the introduction and continuation of energy subsidy to expand groundwater development (Janakarajan and Moench, 2006). Power subsidy was one of key factor to increase groundwater overdraft problems (Moench, 1993). During 1960s there was low agricultural production and general food shortage and to overcome this Government has started implementing agricultural input subsidy policies. Consequent technological advancement and support price policy led to increased groundwater extraction rates and water requirement of agriculture sector has gone up to 170 per cent in the past one and half decadeSingh (2011).

Agricultural electricity subsidy in the form of free power was introduced for improving groundwater development and this possiblyfacilitatedincrease agricultural production. In Tamil Nadu state free power for agriculture was introduced in early 1990s. Due to this free electricity the energy consumption per hectare is highest (19.95 GJ/ha) in Tamil Nadu statehowever its productivity of food grains were relative low (2175 kg/ha) (Jha, 2013). On the other hand, indiscriminate drilling of wells, with their aggregate capacity far exceeding the utilizable resources in the shallow aquifers, was causing well interference and fast drying of shallow wells (Kumar*et al.,* 2011).

Janakarajan and Moench(2006) studied progressive decline of groundwater induced by competitive deepening of wells in Tamil Nadu. It has resulted in increased cost of well irrigation and new form inequityhas emerged between well-owning and non-well owning farmers.Where groundwater overdraft witnessed,this could possibly lead to changes in cropping pattern.

Methodology

The study was carried out in Tamil Nadu state where energy-irrigation nexus considered as major factor for selection of crop enterprises. This study comprises of two parts; first part was to estimate share of different sources of irrigated area (surface and well irrigation) to net irrigated area and to estimate the trend of electricity consumption through number of pump sets electrified in the regions. Firstly, all districts of Tamil Nadu hadbeen chosen purposively to assess the trend of different sources of irrigation, area under different crops and number of pump sets electrifiedin agriculture sector. Data wascollected regarding above said variables from 1991-92 to 2010-11 from various issues of Season and Crop Report and Tamil Nadu Electricity Board (TNEB). Since 1990, electricity was being provided to the farm sector at free of cost and individual consumers are not metered.Hence measuring electricity consumed by pump setsused for agriculture is difficult. In the absence of direct measurements farm power consumption is obtained as a residual by deducting consumption by other sectors including estimated transmission and distributional losses (T&D) from total power consumed (Gulathi, 1992. Summary statistics were worked outand correlationswere analysedto study the degree of relationships among well area, rainfall, area irrigated by different sources and number of pump sets electrifiedover the years, at each district level and state as a whole. For conducting second part of primary survey analysis districts were selected based on highest share of number of pump sets electrified and well areato net irrigated.

Thiruvannamalai, Coimbatore and Erode districts were for conducting field survey. During field survey of farm households information on depth of wells, depth of water availability during different monsoon periods, number of pump sets and type of motors, power supply per day, area under different crops and its productivitywere carefully collected usingstructured interview schedules. Wells are the major sources of irrigation in the selected districts though surface sources also contributed significant shares to the net irrigated area. However, availability of water throughout crop maturation periods, efficiency and productivity wereobservedto behigh in ground water irrigated areas as compared to surface area. These facts arecontribute for theincreased deepening,and intensity of well water usage andpower consumption in the selected area.

Data collection

Secondary data consists of electricity consumption, rainfall, well and surface irrigated area and cropping pattern,which were collected at districts level. Time series data for the period of 1990-2012 for all districts of the state were collected from various issues of Season and Crop Report, Annual Statistical Abstract of Tamil Nadu, Economic Appraisal of Tamil Nadu and State Electricity Board, Tamil Nadu. Temporal data on composite as they existed in 1990 were taken for reasons of comparable data availability. Subsequent subdivisions of districts wereaggregated for capturing relevant changes. Thus 20 composite districts instead of the present 32 districts aggregate all relevant data for analysis. The composite districts are districts are Kancheepuram, Cuddalore, Vellore, Thiruvannamalai, Salem, Dharmapuri, Coimbatore, Erode, Thiruchirappalli, Pudukkottai, Thanjavur, Madurai, Dindugal, Ramanathapuram, Virudhunagar, Sivagangai, Tirunelveli, Thoothugudi, Nilgiris and Kanyakumari.

The details of selected districts and their blocks classification is presented in Table 3.1. Blocks were selected based on highest well area and number of pump sets electrified during the study year (G return, 2010-11) followed by villages basedon the same criteria.Random sampling method was adopted to select 10 farmers in each village. With two villages from each block and two blocks from each district thedistrict sample size was 40 farmers. The study was conducted in three districts with a totalsample size of 120 farmers.

Table 3.1 Details of sample area in the selected Districts (2013-14)(numbers)

Districts	Blocks	Village	Sample size
Coimbatore	Kinathukadavu	Sirukalanthai	10
		Jakkarpalayam	10
	PollachiNorth	Ramapattinam	10
		kumarapalayam	10
Erode	Gopi	Nagadevapalayam	10
		Kugalur	10
	Modakurichi	Vilakkethi	10
		Vadukkapatti	10
Thiruvannamalai	Chengam	Mammalai	10
		Chengam	10
	Thellar	Theyyaru	10
		Thellar	10
		Total	**120**

Source: G return, Assistant Statistical Office, Various districts, 2008-11.

Descriptive analysis

Summary statistics for the collected data comprising mean, maximum and minimum, coefficient of variation, standard deviation wereestimated. Percentage analysis wascarried out for well and surface area, area under different crops and number of pump sets electrified in agriculture sector. In addition, cropping pattern, depth of wells and its water availability from different seasons were also assessed.

Data on sources of irrigation and area under crops irrigated is available for districts, but not the area under a given crop irrigated by a given source in a given district. This was calculated as follows. In a district, assuming A_i is the area under crop ñiò irrigated and $S_j$is the source ñjò irrigating that crop, the area under crop i irrigated by source j may be estimated as

$$a_{ij=} [A_i/ \times A_i] [S_j/\times S_j]$$

Where, A_i includes major irrigated crops such as paddy, sugarcane, coconut, total cereals, total food grains, total fruits and vegetables, total food crops, total oil seeds and total non-food crops. S_j constitute net irrigated area of both well and surface area to gross irrigated area for the temporal period of 1991-2011 at districts level. Hence, a_{ij}results were converted to percentage.

Analyses the trend of well area, different crops and electricity consumption

Net irrigated area by different source of well, electricity consumed by agricultural sector and area under different food crops was analysed using compound growth rate. The following equation was estimated -

$$Y_t = a\, b^t\, e^{ut}$$
$$\ln Y = \ln a + t \ln b + u_t$$

Where,

Y_t = district wise different source of well and surface irrigated area, electricity consumption by agricultural sector and area under different irrigated crops
a = Intercept
b = Regression coefficient
t = Years which takes values, 1,2,é é 20
u_t = Disturbance term for the year t

Factors influencing well area

Well area is influenced by many factors such as rainfall, surface area, electricity consumption per well and time variable added to capture technological intervention over the period to influence well area. After 1990s, electricitywas provided at subsidized rate to farm sector,the study was also carried out from same time period. Therefore, the marginal cost of pumping was zero and statistical figures on farm level electricity consumption were not available. To capture the impact of electricity consumption on well area, number of pump sets electrified to farm sector is used as aproxy variable instead of electricity consumption per well in the model.

The study used panel data for the estimation. Time series period was during 1991-2011 that is 20 year time period and maximum of 20 cross sectional unit, hence, total number of observations were 400. Each cross sectional unit has the same number of time series observations that means each district has 20 years of observations. This type of panel data is called as balanced model. The present study used the following empirical model of multiple linear regression equation given below:

$$\mathbf{Y_{\mathit{it}} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it}}$$

Where,

Y = Well irrigated area (ha)
X_1 =Rainfall (mm)
X_2 = Pump sets (no.)
X_3 = Surface irrigated area (ha)
X_4 = Time
i = i^{th} cross-sectional units {i = 1, 2, é ..20(districts)} and
t = t^{th} time period {t = 1, 2, . .20 (years)}

Panel data model intercept may differ across individuals (here the twenty districts), each districtôs intercept does not vary over time (time invariant). The intercept β_1 suggest that the intercept of each individual cross-sectional unit is time invariant. It may be assumed that the (slope) coefficients of the regressors do not vary across individuals or over time. Hence, in this regression analysis it is assumed that explanatory variables have fixed effects on the dependent variable i.e.well area.

Impact of Groundwater over-draft and power cut on farm income

Groundwater over draft increased cost of well deepening and reduced extraction rate.In addition, power cut hasdeclined pumping hours and it would reduce the extraction rate during crop production period particularly during critical period of crop growth. These two factors seriously affect productivity of crops and end lead to lower farm income through yield losses.Many factors determinefarm income viz., total land holding (ha), depth of well, share of area under irrigation, education level of household head, family size (numbers) and power cut per day. Power cut is having considerable impact on pumping hours especially during summer season.This problem has been in considerable focus since 2008 due to increased gap between demand and supply of power production. Though the problem was slowly overcome by corrective measure taken by State Government yet the farmsreceivedonly 3 hours of power supply per day in the study region during study period. This would directly affect pumping hours and indirectly affect farm income and thereby forcing them to adopt less remunerative crops. The functional analysis based upon above discussed factors is -

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7}$$

Where

Y = farm income (Rs)

X_1 =Total land holding of household (ha)
X_2 = Education of household head
X_3 = Family members (No)
X_4 = Depth of well (feet)
X_5 = Square of depth (feet)
X_6 = Per cent of area under irrigation
X_7 = Power cut per day
N=120 (Number of observations)

Description of Variables

Total land holding of household (ha) :Size of land holdings was collected and converted into hectare per farm. Land holdings varied with cross sectional units.

Education of household head (Number of years): Number of years of schooling undergone by farm head was considered for measuring education which is also a factor for accounting management efficiency.

Family members (Numbers): Number of men and women household members and their working hours per day was crucially enumerated and then converted into common physical unit of number of man days involved engaged infarm crop production periods.

Depth of Well (feet): Depth of both open well and bore well was measuredby feet per well and to overcome the problem of collinearityonly currently functional (bore/open) well is considered for estimationif a farm had both open as well as bore well. In most such cases, bore well water extracted was let into open well for irrigations.

Square of Well depth (feet): Depth of well in term of feet was squared for estimation.

Per cent of area under irrigation: Each farms had different types of land.The enumerator carefully collected data of area under irrigation and dry land area. It wasquantified into hectare per farms.If farmer has both irrigated and dry land area then area under irrigation is onlytaken for estimation.

Power cut per day: Three phase and power supply per day are measured in terms of hours per day and similarly power cut hours per day are also collected and hours of power cut per day was considered in these estimation.

If the explanatory variables are positively significant at 1and 5 per cent respectively in the above equation then it indicate that one unit increase of total land holding of household (ha), education of household head, family members (Number), depth of well (feet), square of depth (feet)and per cent of area under irrigation then farm income increase by givenunits. One hour increasein power cut per day would reduce farm income, if the explanatory variables become negatively significantand vice versa.

Cost of Groundwater over-draft and power cut

The negative externalities of groundwater overdraft may be broadly classified into private costs and social costs. The social costs are borne by community.Costs incurred by state to recharging aquifer, loss in welfare due to more travelling for drinking water, poor groundwater quality, drying of wells due to neighbours action (miss-management of resource, digging more wells, abstracting water from deeper aquifer, etc.), are some of the social costs (Sharif & Ashok, 2011).Subsidies on free electricity are social cost where production and transmission costs are borne by State government. Some farmers paid onetime payment as adeposit to get power connection fortheir pump sets and some farmers are paying flat rate electricity charges for consumption,which are considered as private fixed cost, though marginal cost of pumping is zero.In recent period,due to frequent power cut, cost of repairing and maintenance on electric transmitter and pump sets are increasing burden to both state government and farm sector respectively.

Private costs are simple and easy to estimate while social costs are more complex and dynamic in nature and are difficult to estimate accurately. The social and private costs of groundwater over-draft and electricity consumption co-exist in the social system and are complimentarily related. In this study, direct and indirect costs associated with groundwater over-draft and power cut have been estimated. Direct costs included the investments made on new bore-wells, loss of capital due to drying up of wells, installation charges to new pump sets and loss of unused pump sets due to drying of wells. These costs are termed as ósunk costsô in the case of drying up of wells (inclusion of unused pump sets cost) and óreplacement costsô in the case of new bore-wells (inclusion of new pump sets connection) that have replaced the old wells.

Direct costs are onetime costs and are likely to increase over time along with the drying up of open wells and increase in the number of bore-wells. Indirect costs include loss in netreturns per hectare due to the decline in net sown areaunder irrigation and loss due to the changes in croppingpattern from the more remunerative water-intensivecrops to less remunerative dry crops. Indirect costswere estimated by taking differential net return on major crops of coconut, banana, paddy, sugarcane and vegetables.

Cost of groundwater over-draft and pump sets = Direct cost + Indirect cost

where

Direct cost = Sunk cost + Replacement cost; and

Indirect cost = Net losses due to change in cropping pattern + Decline in net sown area under irrigation (Sharif & Ashok, 2011).

Results and Discussion

Table 4.1 Descriptive Statistics and correlation for area under irrigated crops

(lakhs ha)

	Maximum	Minimum	Mean	Standard Deviation	Correlation
Paddy	21.37	12.62	18.62	2.37	-0.03
Sugarcane	3.91	1.92	2.88	0.48	0.67**
Total fruits and vegetable	3.20	1.82	2.60	0.43	0.96**
Coconut	3.47	1.24	2.44	0.73	0.79**
Pump sets (lakh numbers)	19.33	13.58	0.08	0.02	0.88**
Surface area	8.83	5.30	7.94	0.83	0.05
Well area	16.22	11.67	14.23	1.37	1.00
Rainfall (mm)	1359	663	1003	198	0.51*

** & * indicate significant at one & five per cent level respectively

Source wise area under irrigated cropsand electricity consumption inagriculture

Source wise irrigated area to net sown area and agricultural electricity consumption to total electricity consumption are presented in Table 4.2.Electricity consumption in agriculture sector in the past two decades hasincreased by about 280 per centfrom 4451 Million Units to 12625.

However, the relativeshare of agricultural sectorôs electricity consumption significantly declined from 26 to 20 percent during 1991-92 to 2010-11. This might be due to increased economic activities of the state in general leading to increased demandsfrom domestic, industrial and service sectors.Despite TN Electricity Board witnessingshortage of power production during past years, relative share of area irrigated by wells area to net irrigated area hasconsiderably increased from44 per cent in 1991-92 to 53 per cent in 2010-11. This is indicative of the growing significance of groundwater for irrigation probably aided bysubsidized electricity supply and farmerôs perceived availability of groundwater throughout crop periods. Groundwater irrigated area had positive correlation with energy consumption but was negatively correlated with surface irrigated area as might be expected in the context of reversal of roles in recent decades compared to early sixties.

Relative share of surface irrigated area had consistently declined to about 25 per cent in the past two decades from about 33 per cent. Thus one may perceive an inverse relationship between surface area and net groundwater irrigated area, even as the ratio of net irrigated to net sown area rose to a high 61 per cent in 2010-11 against 45 per cent in 1991-. Finally, it was observed that energy consumption by agricultural sector, groundwater irrigated area and net irrigated areas were all positively related and increasing over the past two decades, possibly due to the massive rural electrification.

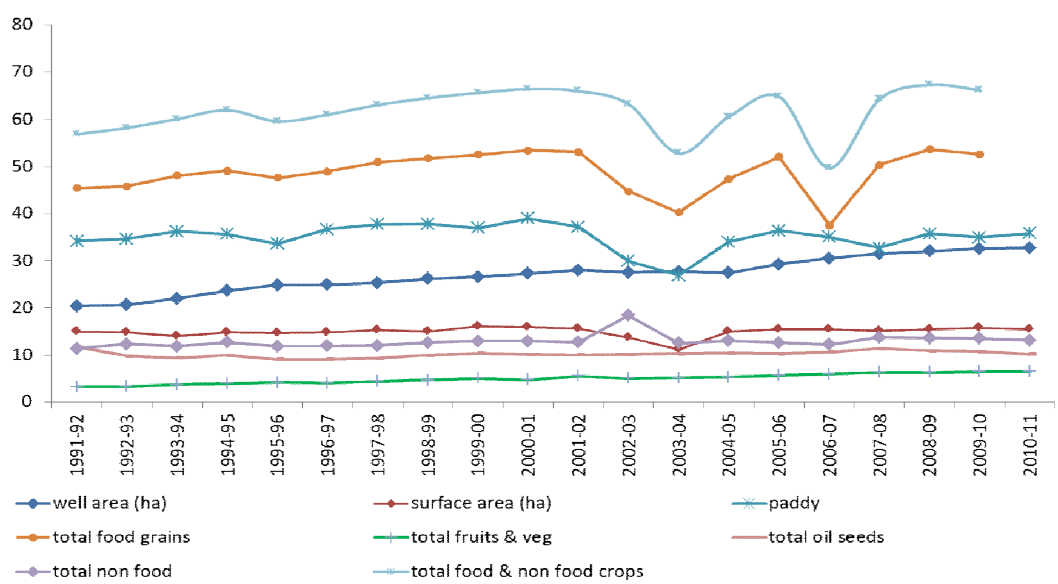
Table4.2 Source wise area under irrigated crops and electricity consumption by agriculture

Particulars	1991-92	1996-97	2001-02	2006-07	2010-11
Electricity Consumption in Agriculture (MU)	4451	6910	9030	7926	12625
Total Electricity Consumption (MU)	17040	25598	36347	39495	61897
Agriculture Power Consumption as % of total power consumption	26.12	26.99	24.84	20.07	20.40
Rainfall (mm)	899	1121	853	851	1207
Well Area (lakh ha)	11.67 (44.83)	13.69 (48.70)	14.50 (49.45)	15.66 (52.29)	16.22 (53.33)
Surface Area (lakh ha)	8.60 (33)	8.16 (29.04)	8.05 (27.48)	7.96 (26.58)	7.64 (25.13)
Net Irrigated Area (lakh ha)	26.05 (100)	28.11 (100)	29.32 (100)	29.95 (100)	30.42 (100)
Net Sown Area (lakh ha)	57.25	54.86	51.72	51.72	49.53
Net Irrigated Area as % of Net Sown Area	45.5	51.25	56.69	57.91	61.42

Note: Figures in parentheses indicate percentage to net irrigated area

Sources: Season and Crop Report and Statistical Abstract of Tamil Nadu, various issues

Share of different sources of irrigation and different food crops to net sown area



Status of energy consumption, sourcesof irrigationand crops grown

Economic considerations, growing groundwater scarcity, increasing well depth and investments on bore wells has been inducing a gradual change away from water intensive to commercial crops. The estimated resultsare presented in Table 4.3. Paddyarea was found to have a declining trend from about 60 to 50 per cent during 1991-92 and 2010-11.This was also partly due to declining net sown area and increase in current fallows. There was a reductionin net sown area of about 20 per cent during above mentioned periods;whilearea under sugarcane had increased from 7 to 11 per cent.

In addition, Sugarcane was being used as asubstitute crop of paddyin both surface and well irrigated area particularly inwell irrigated area where irrigation could be provided throughout the year.The relative share of sugarcane increased while that of rice declined bynearly 10 per cent.Fruits and vegetables share increased from 5.60 per cent in 1991-92 to 9.20 per cent in 2010-11 and area under coconut crop also exhibited an increasing trend in the above periods. However, area under total cereals (63 to 55 per cent), total food grains (65 to 56 per cent) and total food crops (79.90 to 79.30 per cent) were observed to have a declining trend from 1991-92 to 2010-11.

The results reveal that cropping patterns do change slowly but perceptibly due to changes in sources of irrigation aided by agricultural power consumption.In addition,changes in the distribution of rainfall in terms of reduction in number of rainy days during different monsoon periods also had its impact onrecharge of aquifers.

Table 4.3Status of crops grown in Tamil Nadu (in lakh ha)

Year	Paddy	Total Cereals	Total Food Grains	Sugarcane	Total Fruits & Veg	Total Food Crops	Coconut	Total Non Food crops
1991-92	19.58 (60.12)	20.84 (63.70)	21.34 (65.2)	2.38 (7.31)	1.82 (5.60)	26.03 (79.93)	1.25 (3.84)	6.54 (20.08)
1996-97	20.15 (60.20)	21.15 (63.18)	21.48 (64.17)	2.60 (7.77)	2.21 (6.60)	26.90 (80.36)	1.86 (5.56)	6.57 (19.63)
2001-02	19.21 (53.89)	20.33 (57.03)	20.84 (58.46)	3.21 (9.00)	2.85 (8.00)	27.50 (77.14)	2.68 (7.52)	6.62 (18.57)
2006-07	17.96 (52.59)	19.00 (55.63)	19.21 (56.25)	3.91 (11.45)	3.04 (8.90)	27.08 (79.30)	3.14 (9.20)	6.30 (18.45)
2010-11	17.76 (50.92)	19.20 (55.05)	19.76 (56.25)	3.16 (9.06)	3.21 (9.20)	26.97 (77.32)	3.47 (9.95)	6.50 (18.64)

Source: season and crop report, varies issues. Figure parentheses indicate to gross irrigated area

Total cereals includes paddy, maize, wheat, cumbu, solam and coarse cereals

Total food grains includes total cereals and total pulses

Total food crops includes total food grains, total fruits, vegetables & spices and sugar crops

District wise share of irrigated crops and electricity consumption

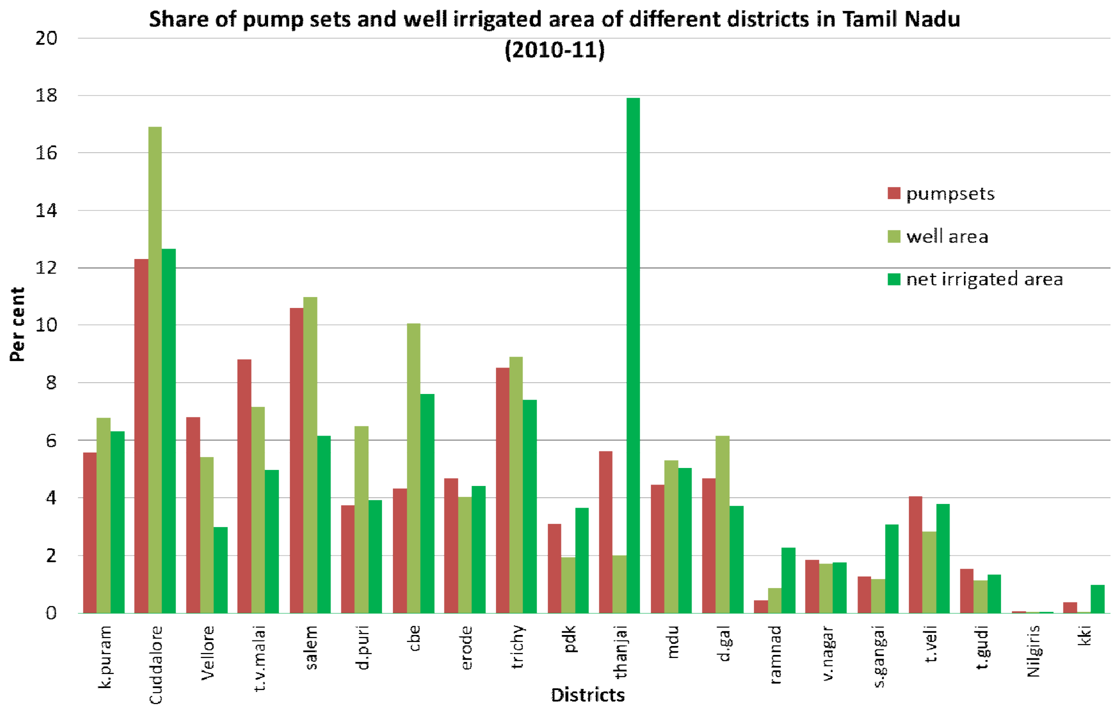
District wise per cent share of major irrigated crops, and pump sets along with their decadal changes are given in Table 4.4. Paddy area declined from 37to 35.11 per cent in Vellore district while there was an increase in Kancheepuramand Cuddalore districts from 55.10 to 61.43 and 43.70 to 52.82 per cent respectively. It was observed that increase in pump sets lead to an increase area under well irrigationand thereby total food cropsis on rising trend. Similarly, share of coconut, total fruits and vegetables in most districts. Pump sets, well area, paddy, area under total cereals, total food grains, sugarcane, total food crops and coconut increased while total oil seeds, total non food crops and surface area declined in Cuddalore district. InVellore district,relative share of total food crops declined.

InThiruvannamalai district paddy (42.41 to 49.34 per cent) and sugarcaneǿs (5.88 to 12.34 per cent)area shares increased in the past decades. In addition, total food grains (46.07 to 50.75 per cent), total fruits and vegetables (0.92 to 3.26 per cent) also increased while,total oil seeds (about eight per cent) and total non food crops (nearly four per cent)declined in above mentioned periods in the district. In Salem and Dharmapuri districts, relative shares declined in area under paddy, total cereals, total food grains, total food crops and sharp decline of surface area but relative share of sugarcane, coconut, total non food crops and well area and pump sets power consumption increased.

A sharp decline in relative share of paddy area was noticed in Coimbatore (12.57 to 5.92 per cent) and Erode (28.90 to 20.04 per cent) districts and it remained same in Trichirappalli during 1991-92 to 2010-11. Power consumption marginally declined in these districts. Coconut share tremendously increased from 27.62 to 53.34 per cent in Coimbatore followed by total fruits and vegetables in the past two decades. Sugarcane crop area increased nearly 13 per cent in Erodedistrict but only marginally in Tiruchirappalli. Finally, total food crops area share increased in Erode and Tiruchirappalli.

Area under different irrigated crops invariably increased in Pudukottai district in past decades; particularly relative shares of paddy (three per cent), sugarcane (five per cent) and coconut (about three per cent). In Thanjavur and Madurai districts, the share of paddy and sugarcane declined by four and two per cent respectively.Increased pump sets and electricity consumption in these districts has been a contributing reason for increased area under coconut and sugarcane followed by fruits and vegetables, total food and non-food crops from 1991-92 to 2010-11 in Pudukottai and Madurai districts. Though,number of pump sets increased in Thanjavur districts area under food and non-food crops percentage declined since most of the ground water use was for supplementing paddy irrigation.

Area under coconut crop increased to 14, 6 and 9 per cent respectively Dindugal, Ramanathapuram and Viruthunagar districts. Relative share of paddy was noticed to be declining from 24.43 to 15.68 and 84.71 to 80.71 per cent respectively in the same districts from 1991-92 to 2010-11. Newly emerged water intensive crops such as fruits and vegetables, and oil seeds shares were observed to have increased trend with upward trend of total non-food crops while total food crops declined both Dindugal, Ramanathapuram districts.



Water intensive crops paddy and sugar cane shares declined at nearly 10 and 11 per cent respectively during 1991-92 to 2010-11 in both Sivagangai and Tuticorin districts however in Tirunelveli, their shares marginally increased. Total food crops share increased in Tirunelveli district but decined in Sivagangai. Fruits and vegetables share increased from 56.67 to 99.57 per cent during 1991-92 to 2010-11 when compared to other crops such as total food and non-food crops in Nilgiries district.

Table 4.4 District wise share of different source of area irrigated and power consumption by agriculture sector (ha)

Districts	Years	Paddy	Total cereals	Total food grain	Sugarcane	Total fruits and Vegetable	Total food crops	Coconut	Total oil seeds	Total non food crops	Pump sets (Number)*
Kancheepuram	1991-92	242199 (55.1)	247244 (56.25)	253803 (57.74)	12413 (2.82)	4362 (1	271548 (61.78)	1214 (0.28)	54942 (12.5)	55996 (12.74)	97833 (7.2)
	2010-11	171840 (61.43)	172341 (61.61)	182090 (65.09)	7737 (2.77)	10445 (3.73	201060 (71.87)	3152 (1.13)	25140 (9)	30672 (10.96)	107711 (5.57)
Cuddalore	1991-92	229492 (43.7)	235342 (44.81)	235999 (44.93)	54513 (10.38)	21501 (4.09)	313160 (59.62)	767 (0.15)	68065 (12.96)	84838 (16.15)	156191 (11.49)
	2010-11	263822 (52.82)	267307 (53.52)	273921 (54.84)	95146 (19.05)	21758 (4.36	394336 (78.95)	2671 (0.53)	24347 (4.87)	44464 (8.9)	237908 (12.31)
Vellore	1991-92	70437 (37)	78011 (40.98)	78920 (41.46)	19753 (10.38)	9334 (4.9	108920 (57.21)	11728 (6.16)	24758 (13)	28209 (14.82)	222069 (16.34)
	2010-11	43222 (35.11)	46771 (38)	46885 (38.09)	14034 (11.4)	11791 (9.58	74368 (60.41)	22134 (17.98)	27649 (22.46)	31666 (25.72)	132192 (6.84)
Thiruvannamalai	1991-92	106834 (42.41)	113632 (45.11)	116067 (46.07)	14054 (5.58)	2313 (0.92	133045 (52.81)	179 (0.07)	40400 (16.04)	41024 (16.28)	2832 (0.21)
	2010-11	125305 (49.34)	126615 (49.85)	128909 (50.75)	31345 (12.34)	8279 (3.26	169641 (66.8)	486 (0.2)	20765 (8.18)	26219 (10.32)	170560 (8.82)
Salem	1991-92	67580 (24.62)	92547 (33.72)	102388 (37.3)	13827 (5.04)	26927 (9.81	146759 (53.47)	4243 (1.55)	38981 (14.2)	50525 (18.41)	150336 (11.06)
	2010-11	46828 (15.32)	88792 (29.04)	91214 (29.84)	30784 (10.07)	36948 (12.09	175833 (57.51)	20729 (6.78)	36475 (11.93)	63424 (20.75)	204832 (10.6)
Dharmapuri	1991-92	76452 (41.8)	88824 (48.56)	89525 (48.94)	14459 (7.9)	6827 (3.73	112423 (61.46)	8771 (4.8)	19794 (10.82)	35109 (19.19)	65275 (4.8)
	2010-11	39199 (22.45)	45103 (25.83)	45781 (26.22)	20693 (11.85)	26102 (14.95	106647 (61.07)	22146 (12.68)	26262 (15.04)	37680 (21.58)	72139 (3.73)
Coimbatore	1991-92	21287 (12.57)	39545 (23.35)	43415 (25.64)	12402 (7.32)	11196 (6.61	70585 (41.68)	46778 ((27.62)	64644 (38.17)	77623 (45.84)	125711 (9.25)
	2010-11	14463 (5.92)	43415 (17.77)	45049 (18.44)	8383 (3.43)	29081 (11.9	91693 (37.54)	130310 (53.34)	136933 (56.06)	146227 (59.86)	83758 (4.33)

Districts	Years	Paddy	Total cereals	Total food grain	Sugarcane	Total fruits and Vegetable	Total food crops	Coconut	Total oil seeds	Total non food crops	Pump sets (Number)*
Erode	1991-92	75466 (28.9)	80573 (30.86)	84551 (32.38)	14913 (5.71)	7589 (2.91	113444 (43.45)	5644 (2.16)	58157 (22.27)	77537 (29.7)	72304 (5.32)
	2010-11	36616 (20.04)	44289 (24.24)	45238 (24.76)	34479 (18.87)	20348 (11.14	115120 (63.01)	10987 (6.01)	25061 (13.72)	41110 (22.5)	90105 (4.66)
Trichirappalli	1991-92	100727 (43.37)	107021 (46.08)	109887 (47.31)	20413 (8.8)	28037 (12.07	165056 (71.07)	3919 (1.7)	25913 (11.16)	34079 (14.67)	119350 (8.78)
	2010-11	116987 (47.55)	121641 (49.44)	122528 (49.8)	23470 (9.54)	43373 (17.63	195558 (79.48)	11269 (4.58)	31521 (12.81)	39874 (16.21)	165057 (8.54)
Pudukkottai	1991-92	72946 (71.52)	76289 (74.8)	77905 (76.38)	1941 (1.9)	1432 (1.4	81916 (80.31)	586 (0.57)	8210 (8.05)	8950 (8.78)	28726 (2.11)
	2010-11	84998 (75.65)	87897 (78.23)	88410 (78.7)	7858 (6.7)	3681 (3.28	100075 (89.07)	3922 (3.5)	9973 (8.88)	11558 (10.3)	59907 (3.1)
Thanjavore	1991-92	457025 (74.02)	457515 (74.1)	463259 (75.03)	24646 (4.67)	6939 (1.12	495160 (80.2)	664 (0.11)	6761 (1.28)	32830 (5.32)	44944 (3.31)
	2010-11	469994 (70.73)	471085 (70.9)	496054 (74.65)	12709 (3.4)	6272 (0.94	515134 (77.53)	12591 (1.9)	21981 (1.1)	27532 (4.14)	108749 (5.62)
Madurai	1991-92	102537 (46.36)	109602 (49.55)	114026 (51.55)	13499 (6.1)	10550 (4.77	139136 (62.9)	9092 (4.11)	20410 (9.23)	39948 (18.06)	73382 (5.4)
	2010-11	76419 (44.03)	87316 (50.31)	88817 (51.18)	9550 (5.5)	26360 (15.2	126071 (72.64)	26521 (15.28)	29164 (16.8)	35605 (20.52)	86277 (4.46)
Dindugal	1991-92	19665 (24.43)	29984 (37.26)	31523 (39.17)	6032 (7.5)	12367 (0.3715	53053 (65.92)	7533 (9.36)	19678 (24.45)	23728 (29.48)	58603 (4.31)
	2010-11	18349 (15.68)	40243 (34.38)	40794 (35.85)	5256 (4.5)	21619 (18.47	69250 (59.17)	27982 (23.91)	36050 (30.8)	45628 (38.98)	90045 (4.66)
Ramanathapuram	1991-92	56528 (84.71)	57353 (85.95)	57414 (86.04)	85 (0.13)	316 (0.47	61571 (92.27)	4116 (6.17)	4604 (6.9)	5159 (7.73)	56074 (4.13)
	2010-11	55157 (80.05)	55303 (80.92)	55368 (81.02)	550 (0.8)	575 (0.84	60014 (87.81)	8363 (12.24)	8497 (12.43)	8887 (13)	8348 (0.43)
Viruthunagar	1991-92	19550 (30.5)	26067 (40.66)	28906 (45.09)	4714 (7.35)	3728 (5.82	41203 (64.27)	4873 (7.6)	8055 (12.57)	17829 (27.81)	357 (0.03)
	2010-11	28877 (48.64)	31413 (52.92)	31793 (53.56)	3314 (5.58)	6111 (10.29	43308 (72.95)	9512 (16.02)	10177 (17.14)	12713 (21.42)	35576 (1.84)

Districts	Years	Paddy	Total cereals	Total food grain	Sugarcane	Total fruits and Vegetable	Total food crops	Coconut	Total oil seeds	Total non food crops	Pump sets (Number)*
Sivagangai	1991-92	67293 (84.36)	67976 (85.21)	68029 (85.28)	5483 (6.87)	717 (0.9	75930 (95.18)	1830 (2.3)	3101 (3.89)	3711 (4.65)	602 (0.04)
	2010-11	67531 (75.15)	67590 (75.21)	67605 (75.23)	5219 (5.81)	2902 (3.23	80435 (89.51)	6599 (7.34)	9085 (10.11)	9428 (10.49)	24315 (1.26)
Thirunelveli	1991-92	98975 (48.74)	102897 (50.67)	103896 (51.16)	4585 (2.26)	12684 (6.25	128330 (63.2)	5667 (2.8)	12808 (6.31)	23875 (11.76)	49739 (3.66)
	2010-11	79764 (49.9)	83955 (52.52)	85614 (53.56)	4776 (3)	22217 (13.9	114399 (71.56)	12098 (7.57)	13021 (8.15)	18207 (11.4)	78384 (4.05)
Tuticorin	1991-92	31947 (47.25)	33030 (4.858)	33290 (49.23)	232 (0.34)	10912 (16.14	46894 (69.35)	3528 (5.22)	4956 (7.33)	8359 (12.36)	34036 (2.5)
	2010-11	20007 (38.27)	21970 (42.03)	22463 (42.97)	562 (1.08)	14802 (28.31	39120 (74.83)	5842 (11.18)	6125 (11.72)0	7143 (13.66)	29608 (1.53)
Nilgiries	1991-92	158 (23.69)	158 (23.69)	158 (23.69)	0 (0)	378 (56.67	537 (80.51)	0 (0)	130 (19.49)	130 (19.49)	673 (0.05)
	2010-11	13 (2.77)	13 (2.77)	13 (2.77)	0 (0)	447 (95.31	467 (99.57)	0 (0)	0 (0)	2 (0.43)	1280 (0.07)
Kanniyakumari	1991-92	40572 (48.63)	40572 (48.63)	40572 (48.63)	0 (0)	3919 (4.7	44598 (53.46)	3420 (7.03)	3442 (4.1)	4067 (4.13)	3533 (0.26)
	2010-11	16989 (35.93)	16989 (35.93)	17049 (46.29)	6 (0.01)	7461 (15.65	24689 (51.78)	10088 (21.16)	10091 (21.16)	12300 (25.8)	7214 (0.37)
STATE	1991-92	1957670 (48.03)	2084182 (51.2)	2133533 (52.4)	237964 (5.84)	182028 (4.47	2603268 (63.92)	124552 (3.06)	671508 (16.5)	653526 (16.05)	1358779 (100)
	2010-11	1776380 (46.3)	1920048 (50.03)	1975595 (51.48)	315871 (8.23)	320572 (8.35	2697218 (70.3)	347402 (9.05)	508317 (13.25)	650339 (16.95)	1933320 (100)

Note: Figures in parenthesis indicate per cent of irrigated area to gross irrigated area, * indicateper cent to total power consumption in the state

Growth of area under irrigated cropsand power consumption in agricultural sector in Tamil Nadu

Decadal growth ratesin area irrigated by groundwater and surface sources, different food and non food crops, power consumption in agricultural sector are presented in Table 4.5.Well irrigated area grew by2.48 per cent during 1991-2000 and at 2.54 per cent per annum in the last decade. The overall growth rate in well area was 1.36 per cent per annum during 1991-2011.Energy consumption growth in agricultural sector wasat7.74 per cent per annum in the previous decade which declined to4.16 per cent per annum during 1991-92 to 2010-11.

Table 4.5 Growth rate of area under irrigated crops and power consumption in agriculture in Tamil Nadu

	1991-2000		2001-10		1991-2010	
	Growth rate	P-Value	Growth rate	P-Value	Growth rate	P-Value
Well area	2.48***	0.00	2.54***	0.00	1.36***	0.00
Energy consumption	7.74***	0.00	2.88	0.12	4.16***	0.00
Surface area	0.09	0.82	1.76	0.27	-0.80*	0.08
Paddy	0.39	0.52	1.48	0.36	-1.18**	0.02
Total cereals	0.31	0.60	1.74	0.27	-1.06**	0.04
Total food grains	0.31	0.60	1.21	0.66	-0.69	0.31
Sugarcane	2.99*	0.06	2.61	0.29	1.00	0.15
Total fruits and vegetable	4.10***	0.00	3.24**	0.01	2.69***	0.00
Total food crops	0.90*	0.08	1.84	0.30	-0.70	0.17
Coconut	7.37***	0.00	2.88**	0.00	5.61***	0.00
Total oil seeds	-1.36	0.18	-0.64	0.95	-2.63	0.26
Total non- food crops	0.14	0.81	-0.63	0.57	-0.23	0.43

Note: ***, ** & * indicate significance at 1, 5 & 10 per cent respectively

Among the food crops, growth rate in total fruits and vegetables was at 4.10 per cent per annum and 3.24 per cent during 1991-2000 and 2001-10 respectively. A steep fall of energy consumption and well area had marginaldecline of overall growth rate at 2.69 per cent per annum during 1991-2011. The growth in sugarcane was high at 2.99 per cent per annum in the previous decades and not so significant in the current decade. Growth in total food crops was found to be positive but less than one per cent per annum past decade 1991-2000 and not significant in the current decade. Growth in coconut witnessed as increasing trend at 7.37 per cent per annum during 1991-2000 but in the current decade declined to 2.88 per cent per annum.

There was negative growth in surface irrigated area, paddy and total cereals. Negative growth in surface area was less than one per cent per annum in past two decades followed by paddy area which had about one per cent negative trend in the same periods.

Factors influencing well area

To quantify factors influencing well irrigated area,regression analysis was employed with explanatory variablesrainfall, surface area and numberof pump sets electrified.Results are presented in Table 4.6.R square indicated that 67 per cent of the variations in area under well irrigation were explained the included variables. Among the factors, rainfall and pump sets were positively significant while surface area was negatively significant to area under well irrigation. Rainfallhad a positive effect on well irrigation implying that it is the ultimate source of aquifer recharge and that an mm rise in state rainfall from its mean level would help to increase 14.58 ha under well irrigation.One more added pump would irrigate an additional area of0.78 ha whilechanges in surface area in terms of one ha increasemay compete with aquifer recharge and decreasewell area irrigation by 0.07 ha.

Table 4.6Factors influencing well area (ha)

	Coefficients	Standard error	t ratio
Constant	-1922.94	6413.78	-0.30
Rainfall (mm)	14.38**	5.46	2.64
Pump sets (Noǒs)	0.78**	0.03	28.51
Surface area (ha)	-0.07**	0.02	-3.27
Time	-11.22	304.41	-0.04
R^2 = 0.67, Adjusted R^2 = 0.67			

**, * indicate significant at 1 & 5 per cent level

The results reveal that rainfallhasan influence on area under well irrigation by its nexus with groundwater recharge and availability during monsoon periods. Number of pump sets electrified in the state has increased with the number of new wells and thus directly influence increasing area under well irrigation. On the other hand, it had inverse relationship with surface area that was due to lack of property rights enforcement (in case of tank irrigation), lack of co operations among water user associations and uneven rainfalls distributions. These would be fact for negative significant effect on surface area. However, surface area had remained steady in delta regions where canal irrigation is still predominant source of irrigation.

Results of Farm household primary survey :Socio economic characteristics

Family Size of farm households

The study has been conducted in Coimbatore, Erode and Thiruvannamalai districts of Tamil Nadu. It was observed that nuclear family was the predominant categoryamong sample households.71 (59.17 per cent) respondents had a family size of 4-5 members followed by 40 (33.33 per cent) respondentswith less than four member family size and their average size was only 3 members. It is observed from Table 4.7 that both medium and nuclear family hadpredominant sharein the study area. Only 9 (7.50 per cent) respondents hadmore than 5 members. Thus average size of family members was 4 members of out of 120 sample households.

Table 4.7 Family size of farm households

Family size	Number of family	Average size
<4	40(33.33)	3
4 -5	71(59.17)	5
>5	9(7.50)	6
	120(100.00)	4

Note: Figures in parentheses indicate percentage to total sample farmers

Age of the head of farm households

Age is considered for determining management experience in agriculture. Age distribution of the head of farm households of the sample is furnished in Table 4.8.Age group of between 41-50 yearshas 42(35.00 per cent) respondents followed by 30-40 yearsof age group with 31 (25.83 per cent) respondents and 51-60 years of age group with 28 (23.33 per cent) respondents. There were only 2 respondents less than 30 years of age. The sample being oriented towards assessing water and electricity use in predominantly well irrigated areas, it is interesting to note that majority of farm heads in such areas are in the middle age bracket with an average age of 46.

Table 4.8Age of the head of farm households

Age Group (Years)	Number of Respondents	Average age
>60	17(14.17)	66.64
51-60	28(23.33)	55.88
41-50	42(35.00)	46.33
30-40	31(25.83)	36.31
<30	2(1.67)	26.5
Total	120	46.33

Note: Figures in parentheses indicate percentage to total sample farmers

Education level for head of farm households

Educationlevel of head of farm households aregiven in Table 4.9 and it showsthat 11 (9.17 per cent) respondents were illiterate, 21 (17. 50 per cent)were primary school educated, 60 (50.00 per cent)were secondaryschool educated, 16 (13.33 per cent) were higher secondaryschool educatedand 12 (10.00 per cent)were Collegiate level educated. It is seen that majority of the farmers are literates and coupled with their middle age may be receptive to better perceive issues relating to groundwater extraction through well investments and electricity consumption and their impacts on farm income.

Table 4.9 Education level for head of farm households

Educational level	Number of respondents	Per cent
Illiterate	11	9.17
Primary	21	17.50
Secondary	60	50.00
Higher secondary	16	13.33
Collegiate	12	10.00
Total	120	100.00

Experience of Head of Farm households

From the Table 4.10 it isseen that 43 farmers had experience of 10-20 years and 21-30 years respectively followed by 20 farmers with experience of more than 30 years and only meagre numbers of farmers had less than 10 years of experience. The results showed that 10-30 years of experience had more numbers of farmers and overall average experience in agriculture was 22 years and 4 months and it implies that farmers has enough experience to take an appropriate crop choice during power cut and scarcity of water.

Table 4.10 Experience of head of farm households

Experience in Years	Number of farmers	Average experience
<10	5 (4.17)	6.6
10-.20	43(35.83)	16
21-30	43(35.83)	26
>30	29(24.17)	41
Total	120 (100.00)	22.4

Note: Figures in parentheses indicate percentage to total sample farmers

Income level of farm households

Income level of farm households is presented in Table 4.11 and it was observed that on-farm income from agriculture generated more income Rs.32971tothe farm household followed by off-farm incomewhich contributedRs.22360.Main source of off farm income was from livestock activities and some amount from hired labour income and MGNREGA scheme. Non-farm income was only Rs. 9025,from sources such as mechanical work, textile shop and weaving.

Table 4.11 Income level of farm households

Income details	Mean income (Rs)	Per cent
On farm	32971	51.23
Off farm	22360	34.74
Non farm	9025	14.02
Total	64357	100.00

Well and Energy Particulars

Table 4.12 Descriptive statistics for energy and wells

Particulars	Maximum	Minimum	Mean	Standard deviation
Well cost (lakhs)	15.00	0.50	4.89	3.09
Well depth (feet)	83.00	20.00	47.03	13.39
Bore well (feet)	1100.00	200.00	578.50	191.05
Depth of water (feet)	31.33	8.33	14.72	5.04
No of wells	5.00	1.00	1.27	0.63
No of bore well	8.00	1.00	1.62	1.31
3 phase power (hours)	6.00	3.00	3.13	0.60
2 phase power (hours)	21.00	14.00	15.83	1.18
Power cut (hours)	7.00	0.00	5.04	1.34

From the table 4.12itisobserved that well digging costs ranged from a minimum of Rs. 0.50 lakhs to a maximum of Rs. 15 lakhs and minimum with and average investment of Rs. 4.89 lakhsper well. Open well depthsranged from20 to 83 feet withan average depthof 43 feet per well while bore well depths ranged from 200 to 1100 feet. Water availability per wellwas observedat an average depth of 14.72 feet. Number of open and bore wells per farm ranged from five to eight. Duration of three phase power supply per farm was noticedto be average of three hours per day subsequentlytwo phase supply was for around 15 hours and power cut was nearlyfor 5 hours per day.In Coimbatore and Erode districts bore wellsare used to extract groundwater, collected open wellsand is further pumped from them for crop production purposes. It is perhaps a reason for increased bore well depth of maximum 1100 feet and minimum of 200 feet in the study area.

Pump set Installation and maintenance

Capacity of pump sets and their maintenance charges would be deciding factors forextraction of groundwater.In the study area, majority of farmsreceived electricity connection atsubsidised rateand very few farmsonly paid one time instalment to the Electricity Boardduring pump setelectrification. It is seen in Table 4.13 that about 81 (67.50 per cent) respondentsreceived free power connections at zero marginal costwhereas 34 (28.33 per cent) respondents paid Rs.10000 as onetime instalmentfollowed by 4 (3.33 per cent) respondentsand one respondent whopaid Rs. 25000 and Rs.50000 respectively as onetime payment to the Electricity Board.

Table 4.13 Installation charges to the pump sets

Amount paid (Rs)	No of respondents	Per cent
No	81	67.5
10000	34	28.33
25000	4	3.33
50000	1	0.83
Total	120	100

Cost of Groundwater over-draft and power cut

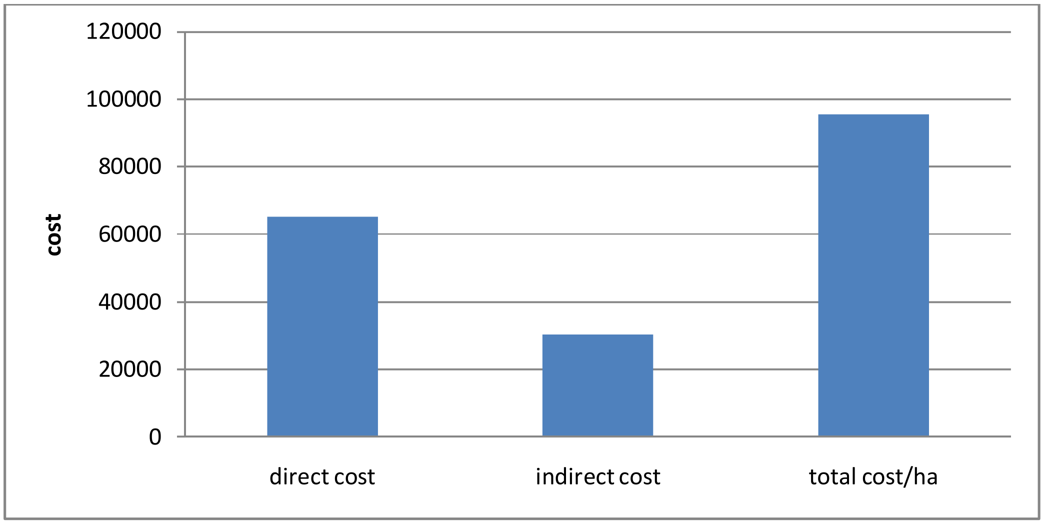
Cost of groundwater over-draft and power cut includes both direct and indirect costs in which direct costs include investmentsmade on digging new bore-wells and loss of capital due todrying up of wells, pump sets failure and maintenance and repair cost during power cut periods. In addition, indirect costs include loss of net income per ha because of changing cropping and yield reductions due to water shortage. Both these types of costs were estimated and are presented in Table 4.14. Direct cost has hadhighest share (68 per cent) to the total cost per ha followed by indirect costs which accounted for 32 per cent. Indirect cost was estimated by taking differential of major crops grown in the study area like banana, coconut, sugarcane, paddyand vegetables. High direct cost was due to frequent power cuts imposed maintenance costs and failure and abandonment of wells.

Table 4.14Cost of Groundwater over-draft and power cut

Particulars	Farm cost (Rs per ha)
Direct cost	162966 (68.25)
Indirect cost	75821 (31.75)
Total cost	238788 (100)

Note: figure in parenthesis indicate percentage to total cost

Figure.1 Cost of groundwater over-draft and pump cut



Water table, pumping hours and area under irrigated crops

Maximum depth of water during different monsoon periods, running hours per day and area under irrigations are presented in Table 4.15. Depth of water availability was10 feet out of 80 feet wells during South West Monsoon (SWM) while it was high 45 feet during North East Monsoon (NEM) and it declinedto13 feet during summer period. Running hours of pump sets per day was highduring NEM (12 hours per day)compared to SWM(6 hours per day) and summer periodsat 3.5 hours per day. Maximum area of about 10ha wasirrigated during NEM followed by 6 haeach during SWM and summerperiods.

It was witnessed from Table 4.16 that depth of water availability was high (14 feet) only during NEM whereas it was only 0.5 feet water out of 20 feet wells during SWM and summer periods respectively. Followed by area under irrigation was 0.2 ha during NEM while it had less than 0.5 ha during Summer and SEM respectively.

Table 4.15 Maximum depth of water, running hours and area under irrigated crops

Particulars	SWM	NEM	Summer
Depth of water (feet)	10	45	13
Running hours/ day	6	12	3.5
Area irrigated (ha)	6	10	6

Average depth of groundwater availability during different monsoon periods was found to be 4.76 feet, 29.33 feet and 4.22 feet out of 47 feet well during SWM, NEM and summer periods respectively. It isseen from Table 4.17 that depth of groundwater was high during NEM (29.33 feet) followed by SWM (4.76 feet) and summer season (4.22 feet). Average pump sets running hours per day was also high (5.92 hours) during NEM period followed by SWM (2.52 hours) and summer (1.26 hours) periods. Area irrigated per farmwas highest at 1.75 ha during NEM compared to other seasons.

Table 4.16 Minimum depth of water, running hours and area under irrigated crops

Particulars	SWM	NEM	Summer
Depth of water (feet)	0.5	14	0.5
Running hours/ day	0.1	2	0.1
Area irrigated (ha)	0.04	0.2	0.05

The resultsshowedthat average depth of wateravailable, running hours and area under irrigationwereinvariably high during NEM due to distribution of rainfall, than other seasons. Canals are major source of recharge for both open well as well as bore well for Coimbatore and Erode districts whereas Tanks are main source of recharge forwells in Thiruvannamalai district.

Table 4.17 Mean depth of water, running hours and area under irrigated crops

Particulars	SWM	NEM	Summer
Depth of water (feet)	4.76	29.33	4.22
Running hours/ day	2.52	5.92	1.26
Area irrigated (ha)	1.20	1.75	1.2

Impact of Groundwater over draft and power cut on farm income

Energy shortage and myopicnature of groundwater resources has major impact on farm income.Factors considered for explaining the impact of groundwater overdraft on farm incomewere total land holding of household (ha), education of household head, family members (number), depth of wells (feet), square of depth, per cent of area under irrigation (ha) and power cut per day. These variables were used as explanatory variables in linear regression estimation and the results are presented in Table 4.18.

Holding size of farms was positively significant at one per cent which means if it increased by one ha then farm income increased by Rs 8800 followed by education of household head, also positively significant at 5 per cent with an additional year of farm education contributing for an additional farm income of Rs 39800. Per cent of area under irrigation and power cut per day were significant with expected signs. Additional per cent unit of area under irrigation positively increased farm income by Rs 1200 while an hour of added power cut per day would reduce farm income by Rs.29000.

Table 4.18Impact of Groundwater over draft and power cut on farm income(Rs.0000'/ha) (Y)

Variables	Coefficients	P-value
Intercept	-17.36 (-0.67)	0.506
Total land holding of household (ha)	0.88*** (4.95)	0.000
Education of household head (Years)	3.98** (2.33)	0.021
Family members (No)	2.44 (1.56)	0.122
Depth of well (feet)	0.45 (0.45)	0.656
Square of depth (feet)	0.00 (-0.27)	0.788
Per cent of area under irrigation (ha)	0.12* (1.73)	0.087
Power cut per day	-2.90* (-1.79)	0.077
R Square	0.374	-
Adjusted R Square	0.335	-
No of observations	120	-

***, **, * indicates 1, 5 & 10 per cent levels of significance respectively; Numbers in parenthesis indicate t values

Impacts of power cut and groundwater over draft on cropping pattern

Shortfall of power and too much deepening and increased intensity of both bore well and open well have forced farm household to adopt crop changes to manage their impacts. Changed cropping pattern was assessed and the results are presented in Table. 4.19. Under changed circumstances total cultivated farm area declined by about 22 per cent compared to relatively better years of water and power availability.

Among the crops, coconut occupied highest share of 54 per cent to total area followed by paddy which accounted for 16 per cent, sugarcane for 11 per cent and banana and groundnut for about 5 and 6 per cent respectively in regular cropping pattern. Vegetables, red gram, maize, turmeric, tapioca and cholam had meagre share of total area. In new cropping pattern water intensive crops like paddy and sugarcane sharply declined to about 8 and 7 per cent respectively followed by irrigated groundnut crop which declined to 3 per cent of total area. Banana and coconut maintained significant share since these crops are annual but their yield levels dropped significantly. Though, Gingelly and flower crops were replaced with maize which also slowly occupied share of area under paddy during thaladi season. Tapioca and red gram area shares marginally increased in new cropping pattern.

4.19Cropping pattern of farm households **(ha)**

Crops	Regular cropping pattern	Changed cropping pattern
Banana	33.50 (4.78)	32 (5.88)
Coconut	379 (54.10)	378 (69.45)
Sugarcane	79.25 (11.31)	35.75 (6.57)
Groundnut	45 (6.42)	14 (2.57)
Vegetables	10.50 (1.50)	2.97 (0.55)
Paddy	117.07 (16.71)	42.27 (7.77)
Tapioca	8.5 (1.21)	16 (2.94)
Red gram	1 (0.14)	2 (0.37)
Turmeric	17.75 (2.53)	9.25 (1.70)
Cholam	7.93 (1.13)	3.07 (0.56)
Maize	1 (0.14)	-
Flower	-	3 (0.55)
Gingelly	-	6 (1.10)
Total area	700.50 (100.00)	544.30 (100.00)

Note: Figures in parentheses indicate percentage to total crop area

Share of vegetables, sugarcane, turmeric and paddy area declined two-three fold compared to regular cropping pattern. Except paddy, other three crops can tolerate rainfall deficiency with groundwater but unscheduled power cuts hamper groundwater irrigation during peak growth, flowering and maturation periods of the crops. This potentially leads to yield loss and drop in net revenue to the farm households. Paddy, with its natural demand for more of water requires more groundwater and energy during droughts which might be a reason for failure of wells during kuruvai and thaladi seasons. Power shortages coupled with water shortage possibly reduced its share in area under irrigation.

Impact of power cut and Groundwater over-draft on cropyields

Declining water availability coupled with reduced three phase power supply to farm sector had negativeimpacts oncrop yields. It could be seen from estimated results presented in Table 4.20thatyields of all major cropsinvariably declined compared to normal period yields. Among them, coconut crop yield loss was a maximum of about 6213 nuts (46 per cent) per ha per annum followed by sugarcane which had loss of 54335 kg (38 per cent) per ha per annum, banana crop with 12500 kg (32 per cent) loss per ha per annum, turmeric and vegetables with 1000 kg per ha per annum and 2583 kg per ha per seasons which were about 22 per cent loss in both periods respectively. Groundnuthad a loss of 11 per cent, red gram 1668 kg per ha per season which was eight per cent and paddy yield loss was 325 kg per ha per seasonwhich was about 5 per cent.

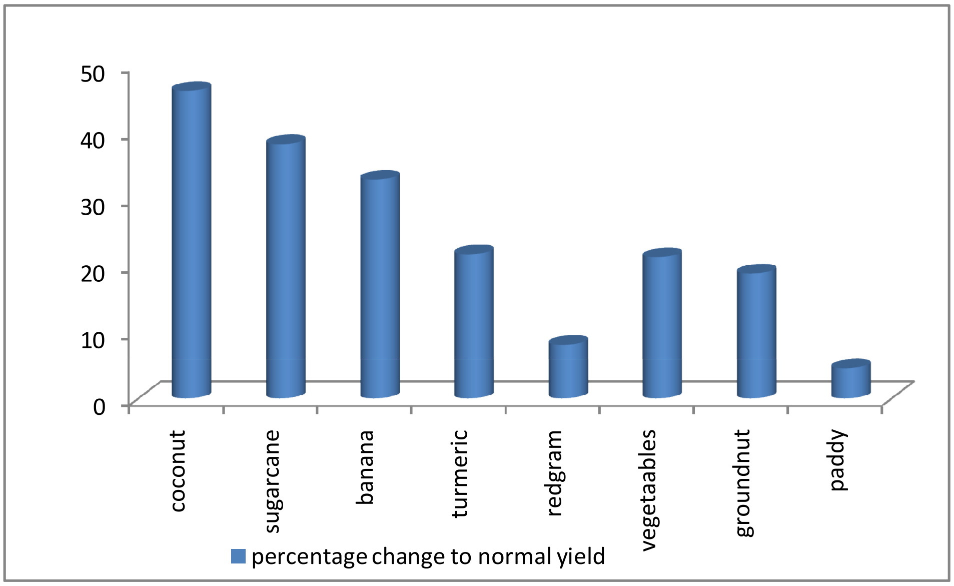
Table 4.20Impact of power cut and Groundwater over-draft on yield loss (kg per ha)

Crops	Normal Yield	Changed Yield	Difference
Coconut	13483	7270	6213 (46.08)
Sugarcane	142610	88275	54335 (38.10)
Banana	38125	25625	12500 (32.8)
Turmeric	4625	3625	1000 (21.62)
Red gram	20668	19000	1668 (8.07)
Vegetables	12205	9623	2583 (21.16)
Groundnut	3093	2513	580 (10.67)
Paddy	7248	6923	325 (4.48)

Note: Figure in parenthesis indicate to normal yield

From table it was clearly found that perennial crop loss was dominant wherever coconut was a major crop. Productivity of coconut was very low at 7-12 nuts per tree in the Coimbatore district during drought and power shortage and to overcome the yield loss water market existed in this region. Red gram and vegetables have been alternative crops to water intensive crops during water and power scarcity due to stabilise farm revenue to some extent.

Figure.2 Impact of power cut and groundwater over draft on yield loss.



Electricity demand supply status in Tamil Nadu

Major reason for the power crisis in Tamil Naduis the absence of long term increase in availability of power by capacity addition and encouraging private investment in power generation compared to other states, over the last 10 years. Following figures demonstrateevolution of gap between requirement and availability of power in Tamil Nadu compared to other industrialized states between 2003-04 and 2010-11.

Fig.3Requirement versus availability of power (2003-04).

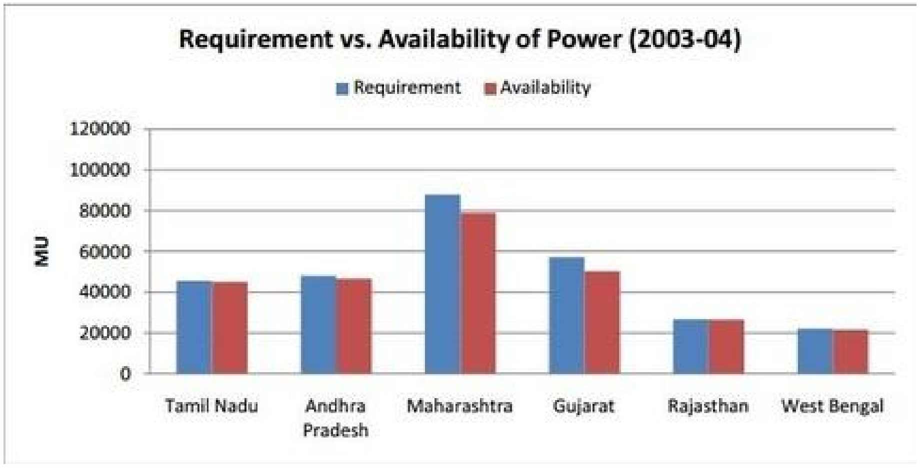
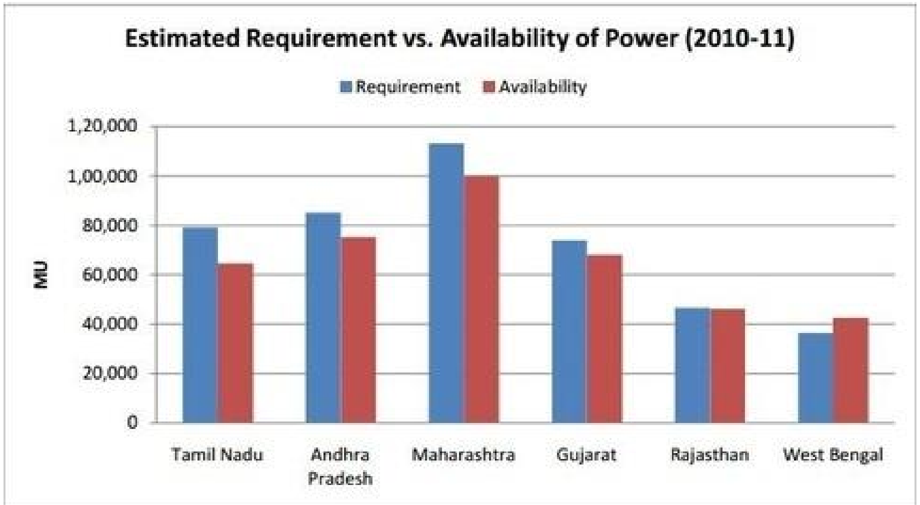


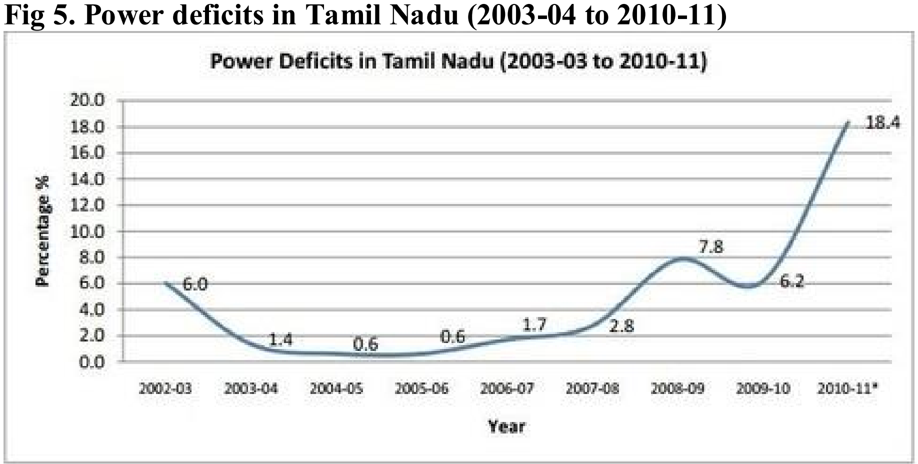
Fig.4 Requirement versus availability of power (2010-11).



Comparing this with the situation in 2003-04, it can be seen that the status of deficits in most of the states was the same, except in Tamil Nadu and Andhra Pradesh. Tamil Nadu, in particular, only had a deficit of around 1% in 2003-04. This deficit has been increasing rapidly, especially in the last five years as can be seen from the graph below:

While states such as Maharashtra, Gujarat and Andhra Pradesh put in added efforts to increase the availability of power both by increasing own capacity and by encouraging private investment in power generation, such a long term increase in availability of power was absent in Tamil Nadu.

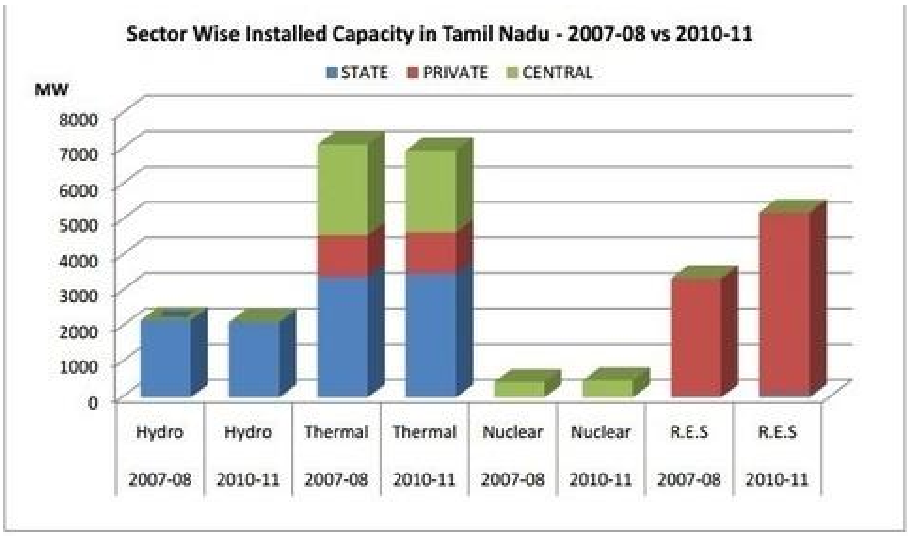
Fig 5. Power deficits in Tamil Nadu (2003-04 to 2010-11)



Overdependence on wind energy

More over all the capacity additions in Tamil Nadu were in private wind generation, which, as mentioned before, is highly seasonal. This can be seen fromthe graph below, which shows sector wise capacity additions over the last three years. Thus as mentioned before, the reason for the low generation by the state sector is the absence of investments by the state in stable internal sources.

Fig 6. Sector wise installed capacity in Tamil Ndu 2007-08 vs 2010-11



These factors that have contributed for power shortages have affected all sectors of the economy by way of load shedding, power cuts and related restrictions. Agriculture sector has also been affected by overall shortage of power. One more aspect to be considered is the non-availability of metered data to accuratley measure electricity consumption in the sector. In such a situation agriculotural sector share is computed as a residual in total power consumption of the state after deducting consumption by all other sectors. The fact that systematic measurements on T&D losses in various sectors are not available and that its share has been recorded almost constant at around 19 percent leads one to suspect that it may be an under estimate in the absence of any major upgrades to the T&D system. To that extent, the recorded electricity consumption in the agricultural sector would be an over estimate.

Even assuming agricultural power consumption data is accurate, growth in the number of pump sets over years, and declining water table indicate the need for more energy to maintain per pump set energy consumption and also to pump the same quantum of water.

Strategies planned for adoption by the state government: (Draft of the 12th Five Year Plan (2012-17) of Tamil Nadu)

(i) Capacity Addition

- Taking up new projects-North Chennai Stage III and IV, Udangudi project and its expansion, Ennore Annex, Kundah Pumped Storage, Uppur thermal power project, ETPS replacement, Tuticorin stage IV, Cheyyur Ultra Mega Power Project etc.
- Speeding up and expediting the completion of on going projects-NorthChennai Stage II, Mettur State III, TNEB-NTPC JV Vallur, TNEB-NLC Tuticorin JV, Kudankulam, PFBR Kalpakkam, Neyveli TS-II Expansion etc.
- Exploring the possibility of adding 10000 MW wind energy through various promoters; Setting up offshore wind power plants;
- Setting up of Solar Parks;
- Attract private investments on a commensurate scale;

(ii) Transmission and Distribution:

- Enhancing transformer capacities in the existing sub stations;
- Bifurcation of high tension overloaded feeders and installation of capacitor banks at distribution transformers for injection of reactive power;
- Conversion of low voltage lines to high voltage lines along with feeder separation to reduce the distribution line losses;
- Segregation of agricultural loads from industrial, commercial, and domestic loads;
- Adequate transmission network to evacuate the power generated fromnew plants and to distribute the customers;

(iii) Energy Conservation

- Implementing Bachat Lamp Yojana (BLY) scheme to increase energy efficiency in domestic sector;
- Improve the efficiency of the agricultural pump sets using appropriate incentive scheme;
- Solar powered home lighting in 3 lakh Green houses; 1 lakh street lights through solar power;
- Energy conservation building code; Energy Star Labeling in Equipments

Conclusions and Recommendations

The main objectives are to assess the temporal and geographical changes in pattern and sources of irrigation and their impact on cropping pattern; to assess the factors contributing for increasing groundwater dependence and pattern of electricity consumption for groundwater irrigation; to assess the impact of groundwater on crop production in the context of rainfall and power availability uncertainties. It was carried out using both secondary and primary data.

Changes in cropping pattern are discernable over the past decades. Broadly area under food grains declined in Tamil Nadu for the past two decades while area under sugarcane, fruits and vegetables and coconut significantly increased. Relative share of agricultural power consumption to total power consumptionhas declined.Relative area shares of Coconut, fruits and vegetables increased in almost all districts whiledeclining trend was noticed in major water intensive crop paddy in Vellore, Dharmapuri, Coimbatore, Salem, Erode, Thanjavur, Madurai, Dindigul, Ramanathapuram, Sivagangai and Tuticorindistricts. Similarly sugarcane area share declined in Kancheepuram, Coimbatore, Thanjavur, Madurai, Dindigul and Virudhunagar districts. Total food crops shares increased in Kancheepuram, Cuddalore, Vellore, Thiruvannamalai, Salem, Erode, Tiruchirappalli, Pudukottai, Madurai, Thirunelveli and Tuticorin whereas total non-food crops increased in Vellore, Salem, Erode, Tiruchirappalli, Pudukottai, Madurai, Thirunelveli, Dharmapuri, Sivagangai and Virudhunagar districts. There was increase in absolute power consumption in all districts and State as a whole even while its relative share exhibited a negative trend. Overall, paddy area declined while sugarcane, coconut, fruits and vegetables area increased in the State.

Area under paddy irrigated, though accounts for the single largest share, has been declining in the State over the decades at about 14,800 hectares per year. This decline has been more or less compensated by the increase in irrigated area under sugarcane, groundnut and coconut. Area under traditionally irrigated crops like cholam, cumbu and ragi has been declining in the same period. These have implications, besides changes in food habits, decline in livestock and fodder needs, for the sources of irrigation as well. The trends also indicate that inspite of concerted efforts improvements in area under pulses and oilseeds (except coconut) could not take off to any significant extent.

Number of wells has been growing at an annual compound growth rate of 1.6 per cent for the past four decades in Tamil Nadu. The rate of growth in almost all the districts except hilly and delta regions is almost equivalent to that of the State. Increase in the numbers of wells has also been translated into corresponding increase in the area irrigated by wells and tube wells. Other than paddy most of the irrigated crops are predominantly dependent on groundwater irrigation through wells with energized pumpsets.

However, excessive dependence on wells, in turn results in the reduction in well yield, drying up of shallow wells, deterioration of water quality, sea water intrusion into the coastal aquifers, increased energy required to lift water from greater depth and its consequent high cost, which becomes uneconomical to poor farmers to continue agriculture. Further many of the agricultural fertile lands have become barren in coastal area like Minjur. In many blocks of the State water resources have been over exploited. With more and more wells being dug and deepened to extract groundwater, increasingly many wells go into disuse since they dry up. The annual compound rate of well numbers being abandoned at the State level has been growing at a very high rate of 2.5 per cent. This indicates that growing dependence on well irrigation has been leading to severe externalities in the form of well abandonment. Well abandonment is closely associated with declining water tables and newer wells need to be dug deeper with increased capital outlay and pumping costs besides the capital lost through the wells abandoned.

Growth rate in well area increased also aidedby free electricity and absolute increase in energy consumption. Surface irrigated area and paddy area had negative trend over the past two decades due to reduced number of rainy days during different monsoon periods and declining groundwater availabilities in an aquifers. From regression analysis, it was observed that rainfall and number of pump sets had positive significant impacts onarea irrigated by wells while surface irrigated area hada negativeimpact.

Majority of farm households depend on farm income and frequent power cut and declining availability of groundwater during deficit rainfall periods adversely affect net farm income. Cost of groundwater over-draft and power cut increases both direct and indirect costs for well deepening and widening. Mean groundwater availability, running hours per day and area irrigated per hectare was high during North East Monsoon compared to other seasons.

Farm survey indicated that farmers experience yield losses varying from about 5 per cent for paddy to more than 50 per cent for coconut during drought periods coupled with scarcity of electricity for pumping ground water. Scarcity of energy is a major issue with respect to canal regions were water intensive crops like paddy banana, sugarcane, and turmeric are the major crops. In such areas groundwater still can supplement canal water during occasional droughts. However since drought periods generally coincide with reduced hydal energy generation dud to low storage in reservoirs energy availability becomes the major limiting factor. Regions normally dependent on groundwater suffer more due to water scarcity during periods of drought. Wells become defunct, deeper and denser with escalating demand for energy even to extract the same quantum of water. In such areas, coconut, being a perennial irrigated crop is worst affected. Other crops also suffer yield losses. Most importantly people try to switch to less water intensive fodder crops or reduce cultivated area to few vegetable crops where market access is available.

In order to manage groundwater table, efforts should be taken for increased recharge through works likedesilting and renovation of existing tanks, watershed development programme at grass root levels with people participation and rainwater harvesting. Electricity is debated to be one of the key components for groundwater over-draft. Appropriate electricity usage policies for agriculture sector might be considered for implementation not only to manage ground water but also to improve the efficiency of power consumed in the sector. Already norms and guidelines have been framed for managing wells and groundwater extraction in the state and they need effective implementation. Similarly the efficiency of pump sets used for groundwater extraction needs to be improved.

Tamil Naduenergy deficit of only around 1% in 2003-04 has been increasing rapidly, especially in the last five years due to the absence of increase in availability of power compared to states such as Maharashtra, Gujarat and Andhra Pradesh which added capacity to increase the availability of power both by increasing own capacity and by encouraging private investment. Moreover most of the added capacity in Tamil Nadu was in the wind energy sector which is seasonal and its production fluctuating.

These factors that have contributed for power shortages have affected all sectors of the economy by way of load shedding, power cuts and related restrictions. Agriculture sector has also been affected by overall shortage of power. One more aspect to be considered is the non-availability of metered data to accuratley measure electricity consumption in the sector. In such a situation agriculotural sector share is computed as a residual in total power consumption of the state after deducting consumption by all other sectors. The fact that systematic measurements on T&D losses in various sectors are not available and that its share has been recorded almost constant at around 19 percent leads one to suspect that it may be an under estimate in the absence of any major upgrades to the T&D system. To that extent, the recorded electricity consumption in the agricultural sector would be an over estimate.

Even assuming agricultural power consumption data is accurate, growth in the number of pump sets over years, and declining water table indicate the need for more energy to maintain per pump set energy consumption and also to pump the same quantum of water.

Policy options

- It needs to be recognized that surface and groundwater are complementary sources and that groundwater is dependent on surface flows and is essentially suited for stabilizing the water delivery to whatever sector requiring it. The objective is clearly to harness as much surface flows as possible through tanks and reservoirs with minimal delivery losses and to the extent possible use the surface water to effectively meet the sectoral demands. A part of the flow may be planned for groundwater recharge to be used as a stabilization reserve. There seems to be no point in looking at groundwater as an independent source of water. Though this appears a simple proposition it may be highly demanding in terms of technical assessments, organizational changes and institutional arrangements for even elementary functionality.

- In future as the stress on the water delivery system will be more pronounced due to growing demands from all user sectors including agriculture, management wouldhe critical on both supply and demand sides, especially on the demand side given that the available resources potential of the State are limited
- On the supply side avoiding delivery losses along the delivery systems, recycling of non consumptive water usage through adequate treatment and optimizing storage reservoirs could help to a limited extent both in canal and tank systems. However, this has to be approached after adequate analysis since already heavy investments have been made in the form of system modernization and the returns real social returns to such investments and cost recovery have not yet been properly assessed and understood.
- On the demand side biggest gains have to come from rationalising water use in the agricultural sector. This might involve reorganizing the cropping, pattern, substituting high water intensive crops with economically comparable less water intensive crops of lesser duration. For instance paddy, to the extent possible may be substituted with less water intensive high value commercial crops.
- Groundwater utilization in the State, now largely unregulated, needs to be rationalized by taking into consideration the potential and actual rechargeappropriate local assessments.
- Besides agriculture, all other sectors using water from the basin shall be made accountable for their water use activities.
- Agriculture sector has also been affected by overall shortage of power. There is need to generate metered data to accurately measure electricity consumption in the sector. Present approach of computing agricultural power consumption as a residual in the absence of systematic measurements on T&D losses in various sectors may not give correct picture of electricity consumption in the agricultural sector.
- Even assuming agricultural power consumption data is accurate, growth in the number of pump sets over years, and declining water table indicate the need for more energy to maintain per pump set energy consumption and also to pump the same quantum of water. Pump set efficiency needs to be improved as also the expansion of present efforts of providing solar pumpsets.

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