Original Research Article

Dynamics in Surface and Groundwater Irrigation Systems across Districts of Andhra Pradesh, India: An Economic Analysis

ABSTRACT

The study explores the district wise irrigation scenario of Andhra Pradesh state with special reference to net tank irrigated area that impacted net groundwater irrigation system in the state. The failure in improvement of tank irrigation due to rainfall, technical, physical and institutional factors gave tremendous scope to improvements in groundwater irrigation system of the state. The study is drawn purely from secondary data sources acquired from DES, Government of Andhra Pradesh. The study examines structural changes in district wise irrigation scenario of Andhra Pradesh state over past 5 decades i.e. from 1970 to 2020. Triennium averages are determined in calculating source wise, district wise irrigation scenario. Net irrigation patterns at the district level were investigated using average and percentage analyses, as well as a tank irrigation scenario. To analyze the trends in district's irrigation water sources over five decades (1970-2020), compound annual growth rate has been estimated by dividing the entire period into two phases of 25 years each i.e. Phase I (TE 1970 – 94) and Phase – II (1995 – 2020). Net canal irrigated area is found to be dominant in districts of Guntur, Krishna, East Godavari and West Godavari with 305, 189, 167 and 150 thousand hectares. Viziaganagaram registered to have highest net tank irrigated of 64 thousand hectares followed by Srikakulam with 51 thousand hectares, Nellore 41 thousand hectares and Visakahapatnam 20 thousand hectares. The overall increase in net groundwater irrigation was found to be highest in districts of West Godavari coupled with canal irrigation and Ananthapur, Chiittoor, Cuddapah and Kurnool districts during TE 2020-21. The districts Ananthapur, chittoor, Cuddapah have less chances of tank irrigation rehabilitation and reclamation as the net reduction is severe due to vagaries of climate. Proper maintenance and rehabilitation program may reclaim the tank irrigation in districts of Vizianagaram, Srikakulam, Visakahapatnam and Nellore.

Keywords: compound growth rate, district wise irrigation status, net canal, net tank, net groundwater irrigation scenarios

1. INTRODUCTION

Many regions of India employ tank irrigation to cultivate crops, primarily paddy, but its prevalence is highest in South Indian states such as Andhra Pradesh, Karnataka, Tamil Nadu and Telangana. Even now, tanks account for 20–30 per cent of the total net irrigated area in several districts of these states. Small bodies of water i.e. tanks have been an essential source of irrigation water in India for centuries. Tanks have offered excellent livelihood protection to rural populations for millennia. Due to the modest size of tanks, the irrigable capacity (command area) of each tank is typically between 50 and 250 hectares. (Raju et al., 2003; Vaidyanathan and Sivasubramaniyan, 2001, Narayanamoorthy et al. 2022).

Despite providing several indirect and direct benefits to the rural community, especially farmers, India's total irrigated area from tank sources continues to decline. From 4.56 million hectares in 1960–61 to 1.89 million hectares in 2013–14, the area irrigated by tanks decreased by around 59 per cent. Andhra Pradesh, Karnataka and Tamil Nadu where tank irrigation is still significant, irrigates a fair portion of land (Narayanamoorthy, 2002; Raju et al., 2004). Tank irrigation has begun to have an impact on groundwater irrigation since tanks play an important role in recharging dug-wells and tubewells in many locations, particularly in South India (A. Narayanamoorthy et al. 2022, Kimberly et al., 2016; Kumar et al., 2016; Narayanamoorthy, 2010 and 2015; Vaidyanathan, 2001).

As the total tank storage is primarily dependent on monsoon rainfall, which is unpredictable, the risk associated with tank irrigation in terms of obtaining an assured water supply for the full crop season is very high. Because most tanks do not receive the intended amount of fillings, crop failure is common when rainfall is below average. This often inhibits farmers from participating in tank management efforts (Narayanamoorthy et al. 2022 and Asian Development Bank, 2006). Some studies attribute the increased spread of groundwater irrigation within the tank command area to this (Naryanamoorthy et al. 2022, Kumar, 2018; Kumar & Vedantam, 2016; Palanisami and Ranganathan, 2004).

The present study primarily concentrates on studying district wise irrigation scenario of Andhra Pradesh state with special reference to surface irrigation water systems like tank irrigation that impacted groundwater system of the state. The failure in improvement of tank irrigation due to rainfall, technical,

physical and institutional factors gave tremendous scope to improvements in groundwater irrigation system of the state. With these facts in view, the main objectives of the study are designed as follows.

1. To study the district wise status of source wise irrigation in Andhra Pradesh
2. To Classify districts of the state based on dominance in source of irrigation
3. To study the source-wise growth in irrigation in districts of Andhra Pradesh

2. MATERIAL AND METHODS

The analysis is entirely based on secondary data sources acquired from several issues of statistical abstracts released by the Directorate of Economics and Statistics (DES), Government of Andhra Pradesh. The study examines structural changes in district wise irrigation scenario of the state agricultural economy over past 5 decades i.e. from 1970 to 2020. Triennium averages are determined to overcome year-to-year variations in calculating source wise, district wise net irrigated area under canals, tanks, tubewells, total groundwater and total net irrigated area of individual districts and state as a whole. Net irrigation patterns at the district level were investigated using average and percentage analyses, as well as a tank irrigation scenario.

To analyze the trends in district's irrigation water sources over five decades (1970-2020), compound annual growth rate has been estimated by dividing the entire period into two phases of 25 years each i.e. TE 1970 – 94 to 1995 – 2020 using log-linear functional form (Kumara KTM and Kumar S, 2019 and Madhurima et al. 2022).

$$LnYt = a + bt \quad \text{... (1)}$$

Where,

Y= Dependent variable (Irrigation water source)

a= intercept

b= Slope and

t= Time

$$\text{Growth rate} = [\text{Antilog (b)} - 1] \times 100 \quad \text{... (2)}$$

3. RESULTS AND DISCUSSION

3.1 District wise status of source wise irrigation in Andhra Pradesh

Since the time immemorial, tanks continued to serve as an important source of irrigation, especially in the southern peninsular India particularly to small and marginal farmers. To cater the

irrigation needs of the resource poor farmers, many were formed during 18th and 19th centuries. Tanks are mainly concentrated in southern Indian states such as Andhra Pradesh, Karnataka and Tamil Nadu though the country occupies a good portion in overall tank irrigation. They are mainly found in arid and semi-arid parts of the tropical country, where tanks area being the main source of irrigation needs. Tank irrigation systems also act as an alternative to pump projects, where energy availability, energy cost, or groundwater supplies are constraints for pumping.

The present discussion continues with the classification of districts in the state according to the dominant source of irrigation to understand the status of irrigation scenario in Andhra Pradesh and for drawing subsequent conclusions on tank irrigation.

Apart from the significance of tank irrigation in the state, the contribution of other sources of irrigation to the total net irrigated area and change over the irrigation scenario had been estimated. Significant makeover has occurred in the landscape scape of irrigation of the state over the decades. The long-term analysis of the net irrigated area in the state revealed that the total net irrigated area increased nearly 1.25 times from 2440.01 thousand hectares during TE 1970-71 to 2963.11 thousand hectares during TE 2020-21 (Table 1).

Table 1 Source wise area under irrigation in Andhra Pradesh ('000 ha)

Source	**TE 1970-71**	**TE 1980-81**	**TE 1990-91**	**TE 2000-01**	**TE 2010-11**	**TE 2020-21**
Canals	1361.47 (55.79)	1476.23 (56.39)	1388.22 (49.59)	1277.88 (47.26)	1298.93 (45.37)	1355.73 (46.18)
Tanks	589.89 (24.18)	542.53 (20.72)	489.68 (17.49)	359.84 (13.31)	303.79 (10.61)	299.06 (10.18)
Groundwater	409.33 (16.78)	519.14 (19.84)	800.04 (28.58)	953.74 (35.26)	1146.61 (40.04)	1172.29 (39.93)
Others	79.32 (3.25)	79.81 (3.05)	121.64 (4.34)	112.67 (4.17)	114.24 (3.98)	109.04 (3.71)
Net irrigated area	**2440.01 (100.00)**	**2617.71 (100.00)**	**2799.58 (100.00)**	**2704.14 (100.00)**	**2863.57 (100.00)**	**2963.11 (100.00)**

Source: Various issues of statistical abstracts, DES, Government of Andhra Pradesh

While canals and tanks were the major sources of irrigation during 1970's and 1980's contributing to nearly two-thirds of the total net irrigated area (Table 1). Over the decades the extraction of groundwater through well irrigation dominated surface water irrigation systems (canal and tank irrigation) in the state contributing to 40 per cent of total net irrigation. Though canal irrigation occupies the

predominant role in state (39.93 per cent), a drastic reduction in overall net tank irrigation (10.18 per cent) substituted with increments in well irrigation have been observed.

Slowly as the decades passed, structural shifts in irrigation scenario of the state is observed with 2.5 times reduction in net tank irrigation substituted with simultaneous increase in groundwater extraction while canals continue to occupy predominant irrigation sources of the state contributing to 46.18 per cent of total net irrigated area (Table 1). Net canal irrigated area is found to be dominant in districts of Guntur, Krishna, East Godavari and West Godavari with 305, 189, 167 and 150 thousand hectares of net irrigated contributing to half of the canal irrigation needs of the state over TE 2020-21 (Figure 1). The major river streams of Godavari and Krishna assists coastal Andhra districts for net canal irrigation needs.

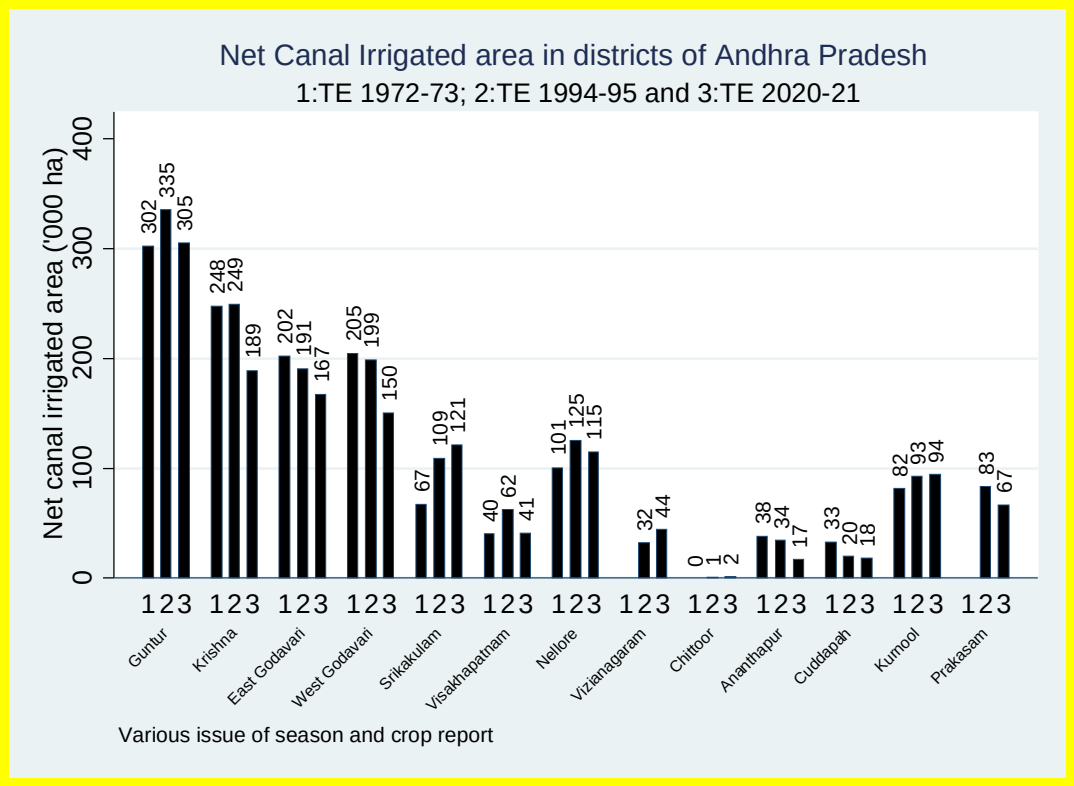


Fig 1 District wise net canal irrigated area in Andhra Pradesh ('000 ha)

Followed by these, Srikakulam, Visakhapatnam, Nellore and Vizianagaram districts occupy 50-100 thousand hectares of net irrigated area under canal irrigation. While Chittoor, Ananthapur, Cuddapah and Kurnool districts of Rayalseema region have least net irrigated area under canal irrigation followed by Prakasam district (Figure 1). Apart from net canal irrigation, net tank irrigation faced a drastic fall among all the districts of Andhra Pradesh, with profound significance in districts in Rayalaseema region of

rainfed, dryland agricultural production with deficit irrigation system implying significant effects rainfall on net tank irrigation of the state (Figure 2).

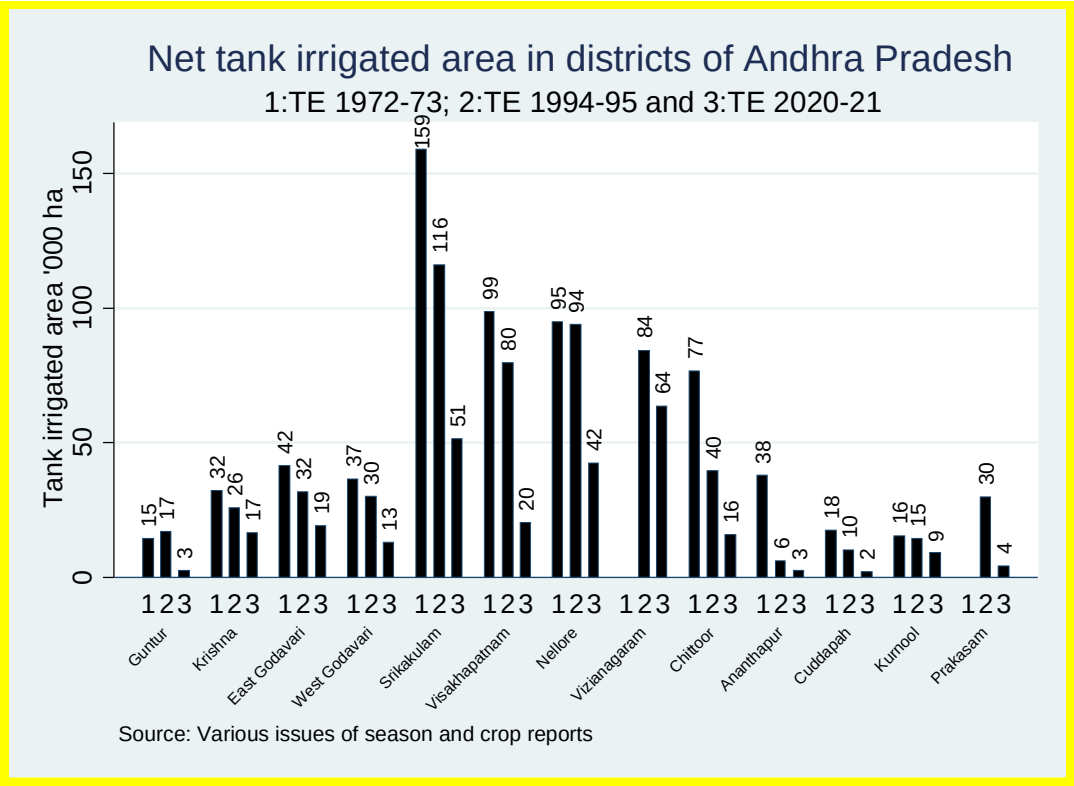


Fig 2 District wise net tank irrigated area in Andhra Pradesh ('000 ha)

Districts of Chittoor, Ananthapur, Cuddapah and Kurnool were observed to have 5 – 10 times reduction in net tank irrigation area over TE 1972 – 73 to TE 2020-21. Irrespective of net reduction all over the state, districts of Viziaganagaram registered to have highest net tank irrigated of 64 thousand hectares followed by Srikakulam with 51 thousand hectares, Nellore 41 thousand hectares and Visakahapatnam 20 thousand hectares (Figures 2 and 4) .

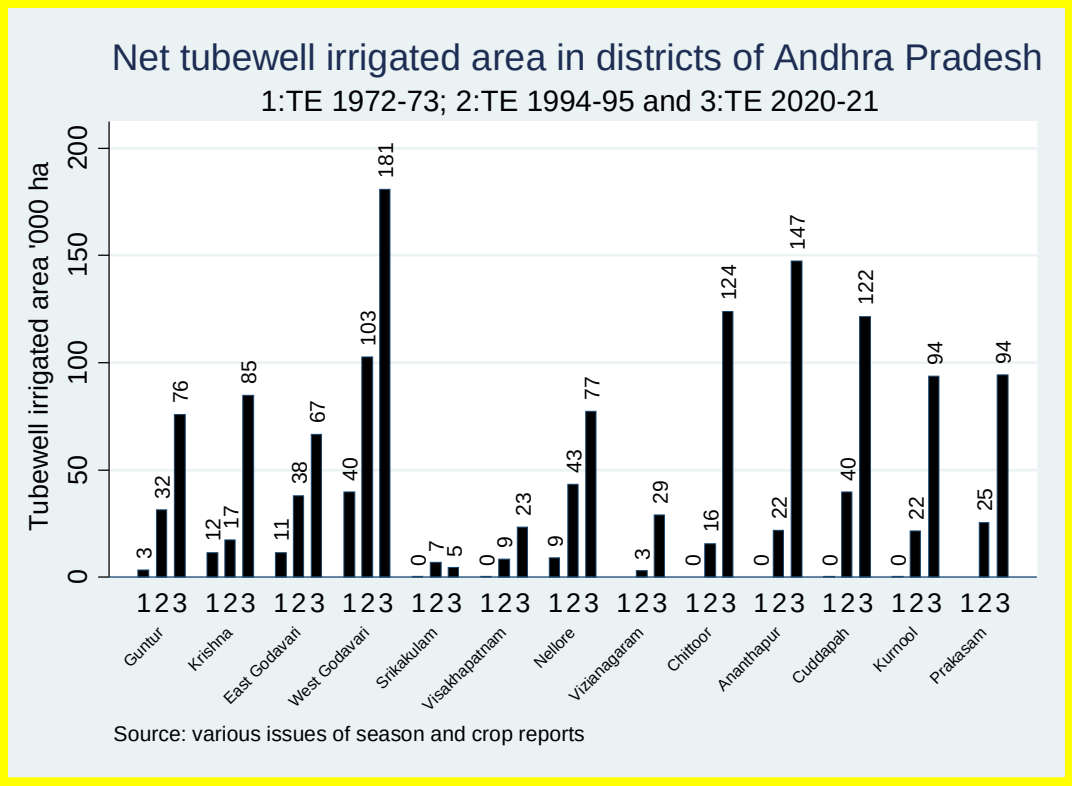
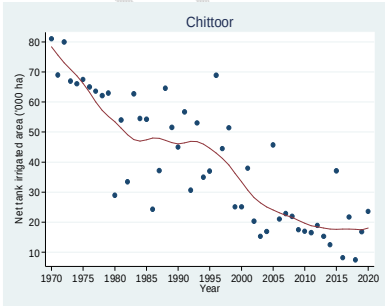
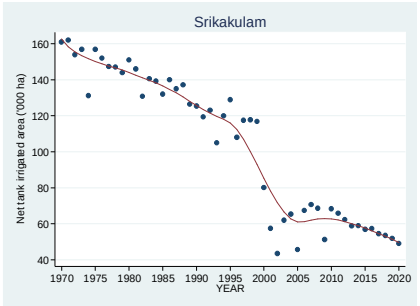
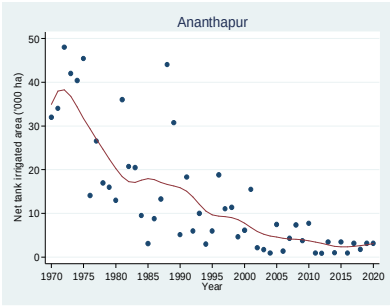


Fig 3 District wise net tubewell irrigated area in Andhra Pradesh ('000 ha)

The two and half fold increase in net groundwater irrigated area by substituting net tank irrigation in the state is prominent among all the districts especially in districts of Rayalaseema region (Figure 5). The increase in net tube wells over TE 1972-73 to TE 2020-21 was 124 thousand hectares, 147 thousand hectares, 122 thousand hectares and 94 thousand hectares during TE 2020-221 among Chittoor, Ananthapur, Cuddapah and Kurnool districts as against 16, 22, 42, 22 thousand hectares during 1972-73 (Figure 3). The overall increase in net groundwater irrigation was found to be highest in districts of West Godavari coupled with canal irrigation and Ananthapur, Chiittoor, Cuddapah and Kurnool districts during TE 2020-21 (Figure 5).







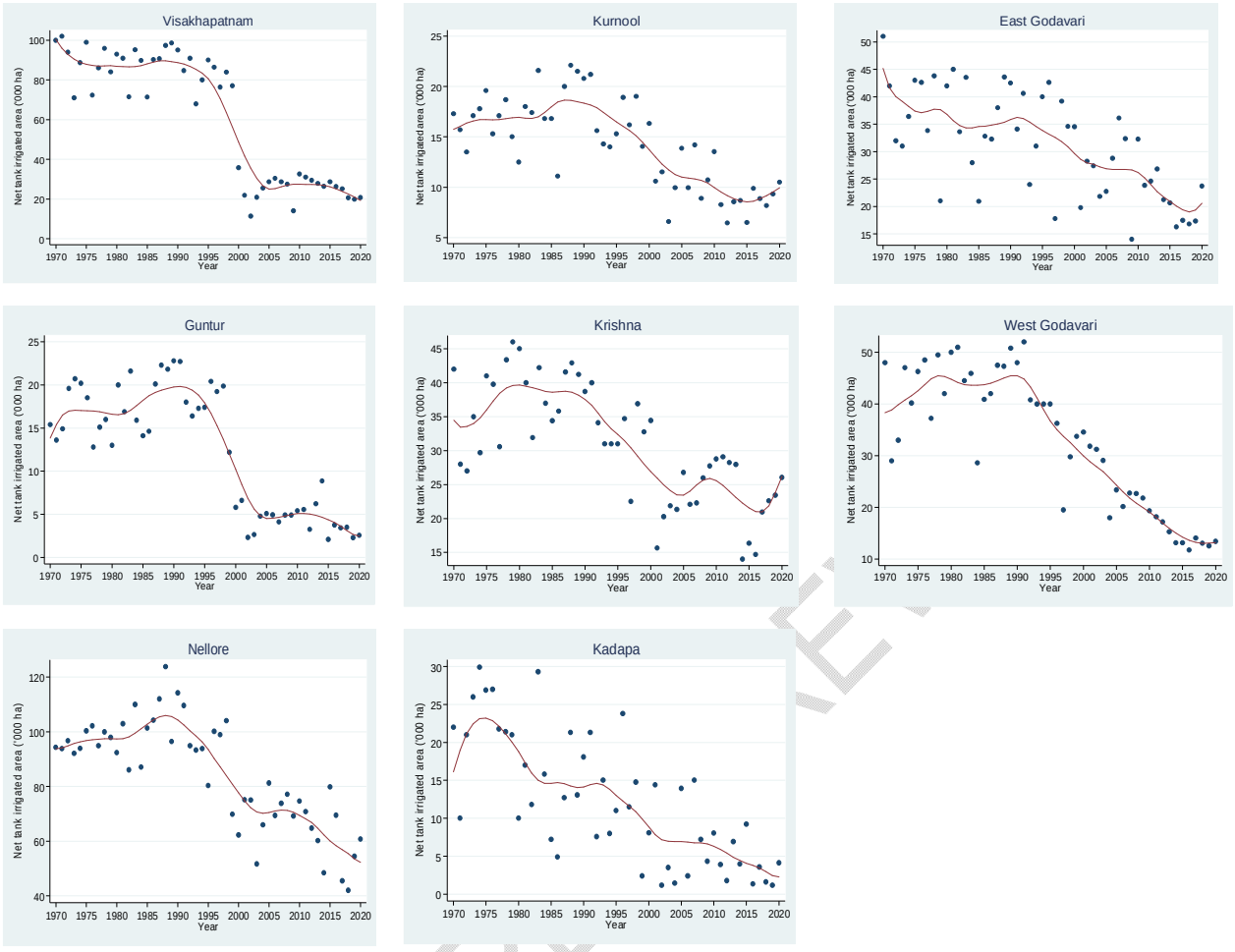


Fig 4 Declining trends in net tank irrigated area across the districts in Andhra Pradesh (1970 – 2020)

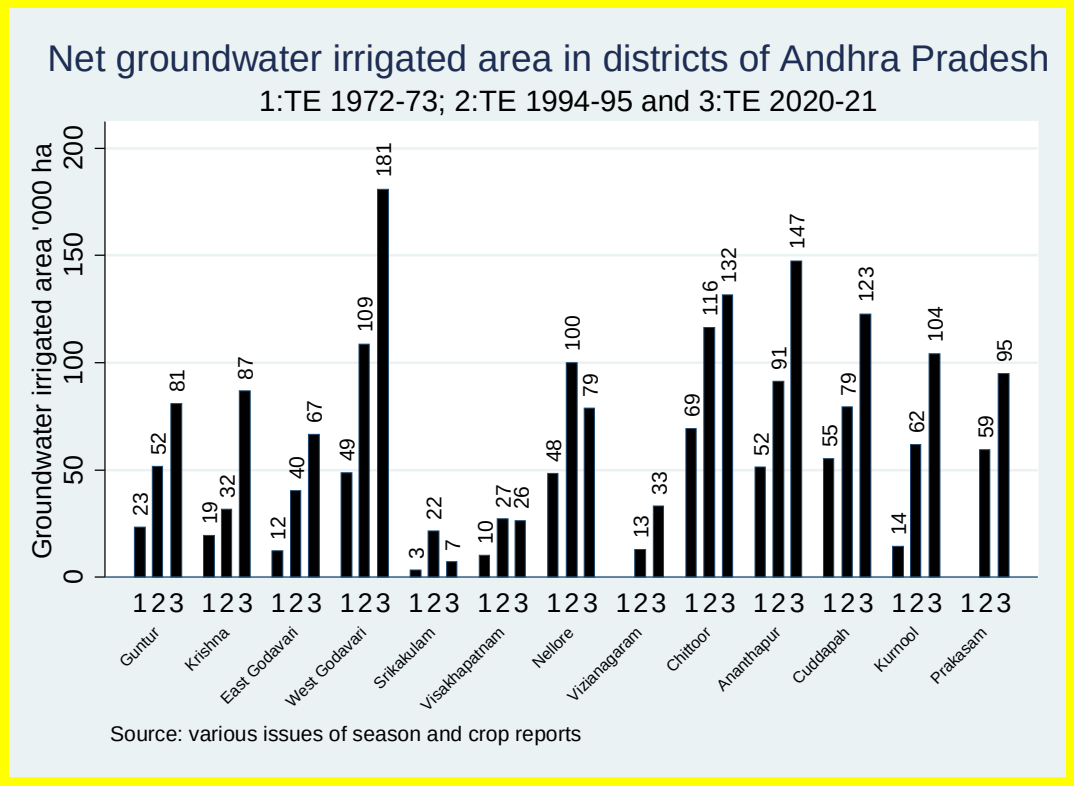


Fig 5 District wise net groundwater irrigated area in Andhra Pradesh ('000 ha)

With increase in net groundwater extraction for irrigation coupled with dominance of net canal irrigation, the net irrigated area in the state had shown a significant improvement over the decades in most of the districts particularly in the districts of Chittoor (149 thousand hectares), Ananthapur (168 thousand hectares), Cuddapah (144 thousand hectares) and Kurnool (228 thousand hectares) (Figure 6).

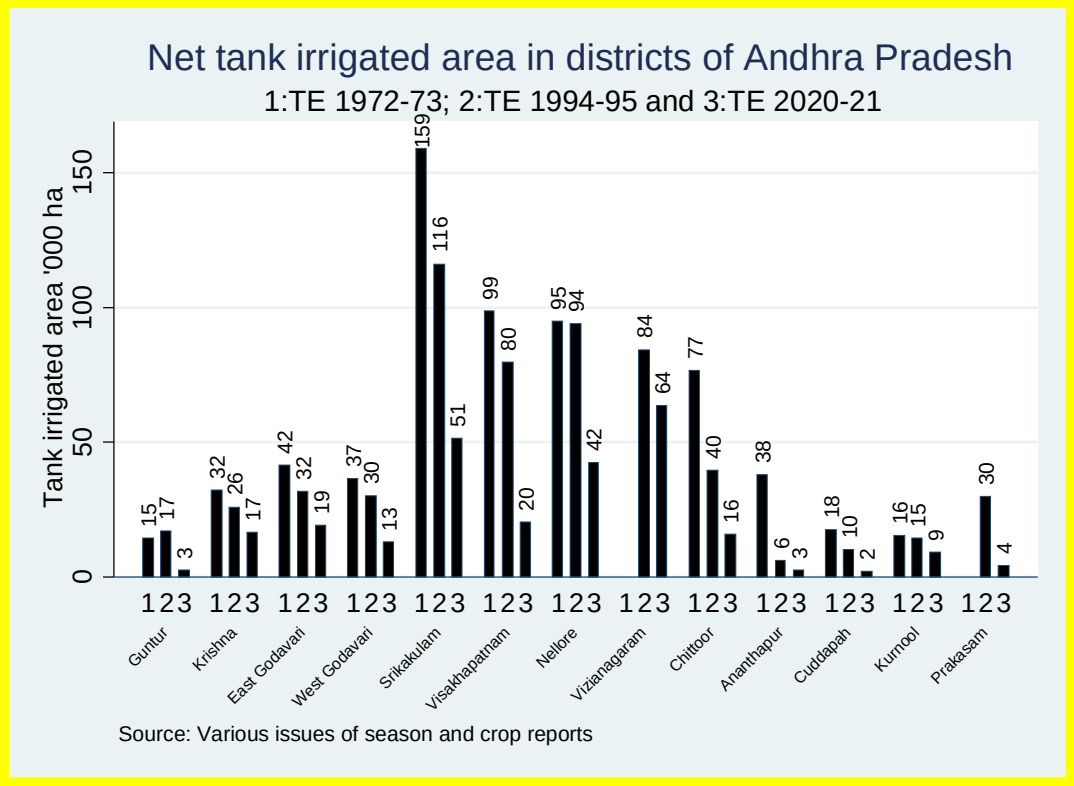
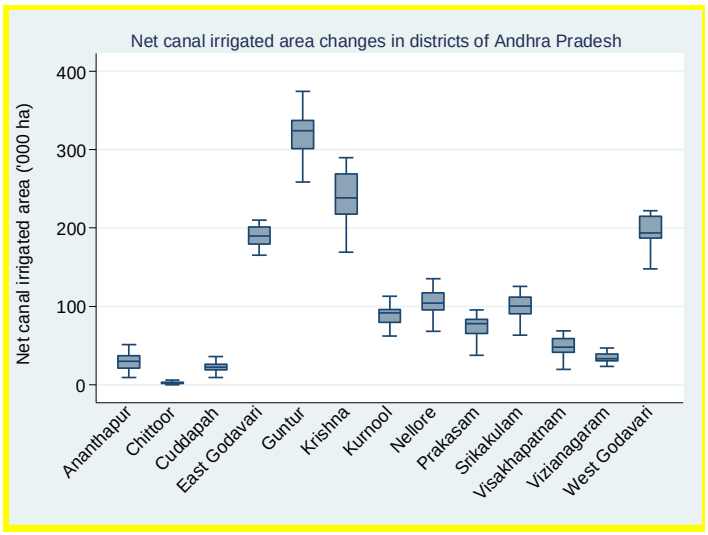


Fig 6 District wise net groundwater irrigated area in Andhra Pradesh ('000 ha)

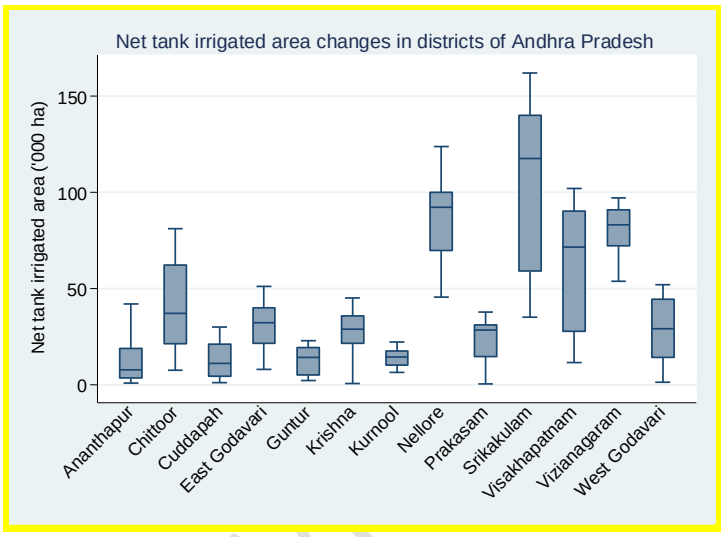
The unpredictability of the state's precipitation has reduced the amount of water that can be stored in tanks, while the elimination of private tank ownership rights and the subsequent diversion of resources toward wells development have both contributed to a decline in tank irrigation's once-prolific use. The findings corroborate those of the investigations by Von and Rao (1987) and Kiran Kumara and Shiv Kumar (2019).

3.2 Classification of districts based on dominance in source of irrigation

Based on the previous results, the discussion continues with classification of districts by different sources of irrigation dominance to comprehend the source-by-source irrigation scenario for the TE 2020-21. Districts were classified into canal-dominated districts, tank dominated districts and groundwater dominated districts for TE 2020-21. Districts of Guntur, Krishna, East Godavari and West Godavari were classified into canal dominated districts as more than half of the increase in net irrigated area is through canals followed by other districts (Figure 7).



(7A)



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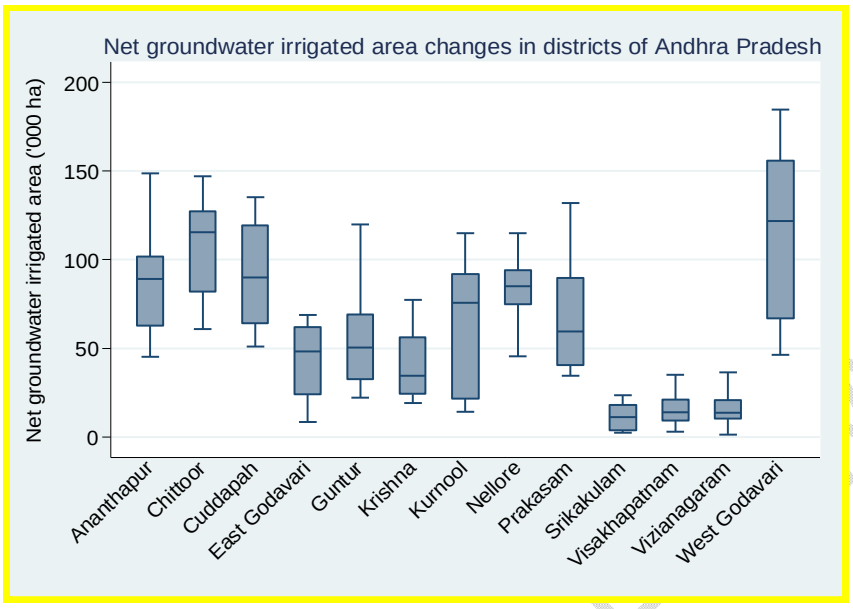
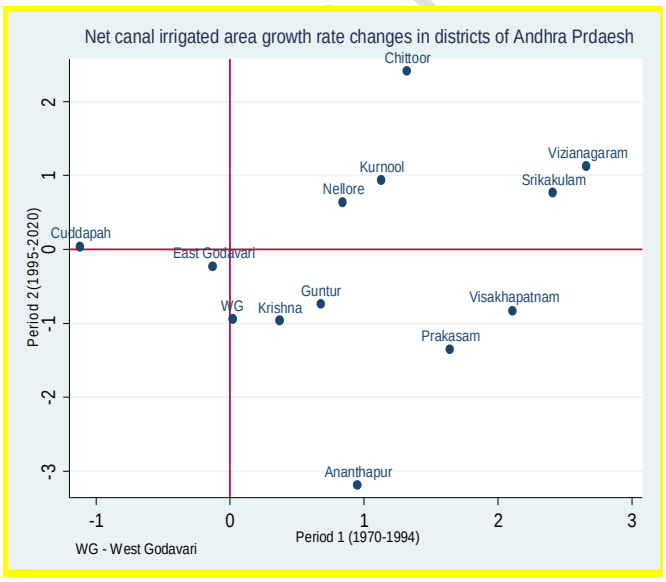


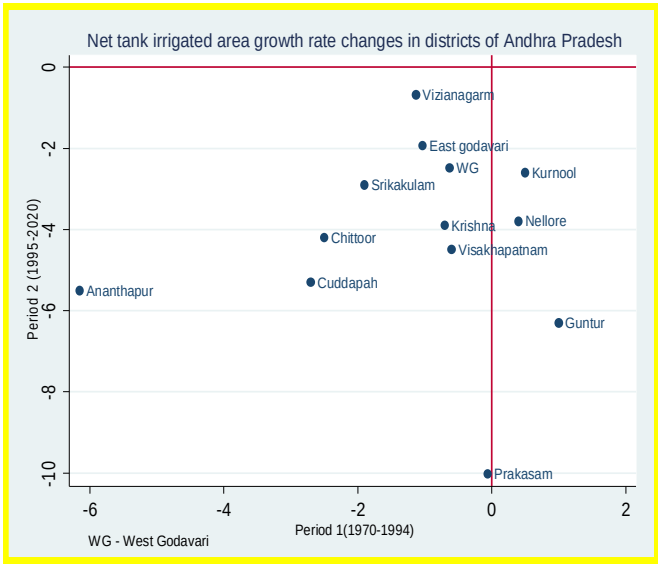
(7C)

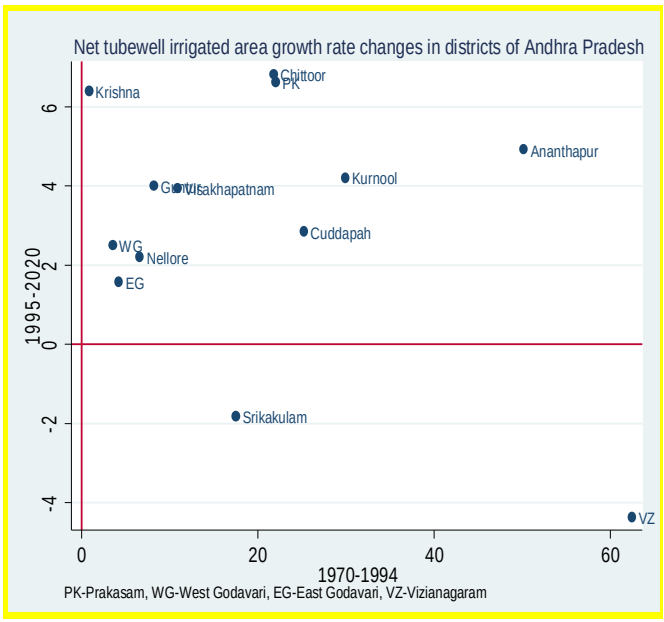
Fig 7(A-C) Classification of districts based on net irrigated area dominance

3.3 Source-wise growth in irrigation in districts of Andhra Pradesh

In continuation to the analysis of structural adjustments in the district's irrigation sources, the growth pattern of each source of irrigation over two stages of 25 years (1970 – 94 and 1994 – 2020) is examined as in Figure 8.







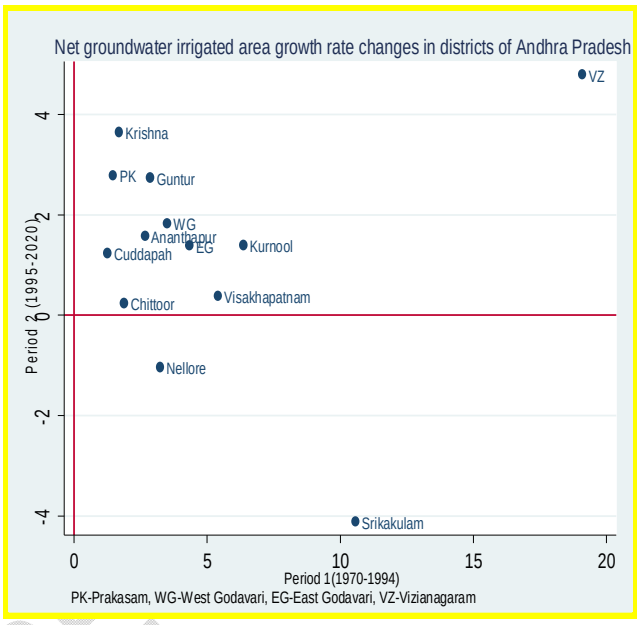


Fig 8 Growth rate in irrigation sources in the state over 1970-94 and 1995-2020

Before and after analysis of growth in net canal, tank and groundwater irrigation sources in districts found that, districts of canal domination i.e. Krishna, Guntur has recorded negative growth during II period (1995- 2020) while Cuddapah district has recorded net rediuction in canal irrigation during I-period (1970-1994). While Prakasam district has recorded -10 per cent reduction in net tank irrigated area and districts of Ananthapur, chittoor, Cuddapah have less chances of tank irrigation rehabilitation and reclamation as the net reduction is severe due to vagaries of climate. While the growth in net groundwater irrigation was found to be significantly positive in both the periods among all the districts (Figure 8). The growth in net tubewell irrigated area shown significant positive growth in both the periods except Srikakulam and Vizianagaram districts where the net tank irrigation are prominent. This demonstrates improvements in the state's groundwater irrigation sources and extraction technology.

4. CONCLUSIONS

The study focuses on structural changes in Andhra Pradesh's district-level irrigation scenario. The state's total net irrigated area expanded approximately 1.25 times from in TE 1970-71 to TE 2020-21, according to a long-term examination of net irrigated area in the

state. Over the years, groundwater extraction by tubewell and open well irrigation has dominated surface water irrigation systems (canal and tank irrigation) in the state, accounting for 40 per cent of total net irrigation. Despite the fact that canal irrigation is the most important in the state (39.93 per cent), a significant decline in overall net tank irrigation (10.18 per cent) has been noted, which has been compensated for by increases in well irrigation.

Net canal irrigated area is found to be dominant in Guntur, Krishna, East Godavari, and West Godavari districts, with total net irrigated area providing to half of the state's canal irrigation needs, respectively. From TE 1994-95, the rise in net irrigated area of tube wells was sharp and observed highly among Chittoor, Ananthapur, Cuddapah, and Kurnool districts. These districts recorded 5 - 10 times decline in net tank irrigated area from TE 1972 - 73 to TE 2020-21. Regardless of reduction in net tank irrigated area across the state, the districts of Viziaganagaram, Srikakulam, Nellore and Visakhapatnam continued to excel in net tank irrigated overall.

Krishna and Guntur saw negative growth during the II period (1995-2020), whilst Cuddapah district experienced net reduction in canal irrigation during the I-period (1970-1994). The district of Prakasam has reported a -10 per cent drop in net tank irrigated area, while the districts of Ananthapur, Chittoor, and Cuddapah have fewer prospects of tank irrigation restoration and reclamation because the net reduction is severe due to climatic vagaries. Except in Srikakulam and Vizianagaram districts, where net tank irrigation is substantial, the growth in net tubewell irrigated area showed significant positive development in both times. Tank irrigation in the districts of Vizianagaram, Srikakulam, Visakahapatnam, and Nellore may be reclaimed with proper maintenance and restoration.

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