

Structural Changes in Irrigation Vis-à-vis Cropping Pattern in Andhra Pradesh, India: An Economic Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The inherent dynamism within a system leads to structural changes of that system. Over the past, the structural changes that are occurring in the world economies are affecting the subsystems one or another way. The development of a nation like India reflects from the development of its states. The current study focuses on the structural shifts within primary sector of Andhra Pradesh (includes Telangana State's data) more precisely, economic linkages between irrigation and between the dynamic changes in cropping pattern. It also explores the implications of dynamic changes happened in state's agriculture after green revolution. The shifts from period 1970 – 2020 are studied using secondary data. Growth rate and conventional analyses (percentages and averages)

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are used to study the effects of shifts in irrigation on cropping pattern of the state. The results exhibit, declining ecofriendly surface water irrigation systems (tanks) by twofold compensated with increased extraction of groundwater resources by fivefold. As a consequence, decline in net cropped area and cropping pattern shifts adopting mono-cropping or double cropping under rice as major crop followed by cash crops or pulse crops under groundwater and canal systems of irrigation aroused. While coarse cereals have lost prominence, cash crops like chilly (93 per cent) have gained importance under irrigation. The prominence of livestock sector in the state can be realized as net irrigated area under fodder crops improved to 50.61 per cent over the decades. Overall improvement in net irrigated area with canal and groundwater systems of irrigation is current scenario of the state. Pressurized irrigation technologies should be promoted to maintain sustainability of tank irrigation structures. Cropping patterns including coarse cereals should be adopted for maintaining nutritional security. Adoption of reclamation measures to attain ecological balance between groundwater and surface water irrigation sources.

Keywords: Structural changes; primary sector; irrigation; cropping pattern.

1. INTRODUCTION

Structural changes are essential for growth and development of an economy. The process of economic development follows a specific pattern rooting from major sectorial changes (primary, secondary and tertiary) to the share of national income and output, following up with whole economy. The general pattern of structural changes in Indian economy followed structural changes associated with continuous fall in share of agriculture sector from 1950's, with development of industrial sector up to certain period (Economic reforms period of 1990's) and final take over by service sector of the economy.

During early 1950's the GDP share of Indian economy was dominated by agriculture sector (52 per cent) followed by services (30 per cent)

and industry (18 per cent) respectively. From 1950 – 1980, economy witnessed a stylized pattern of structural changes with decline in primary sector share to GDP and increase in both industrial as well as services share by 10 per cent and 7 per cent to the overall GDP respectively [1-3]. After 1980's, from 1980 - 2020, the agriculture sector share to India's GDP declined by 19 per cent along with industrial sector by 5 per cent, while services led growth of the country was achieved increase of 24 per cent change. At present, contribution of agriculture and allied to the total GDP is 16 per cent followed by industries (23 per cent) and services with highest share of 61 per cent to the economy [4].

The structural changes in nation's economy have impetus effect on growth and development of individual state's economy [5,6]. The present

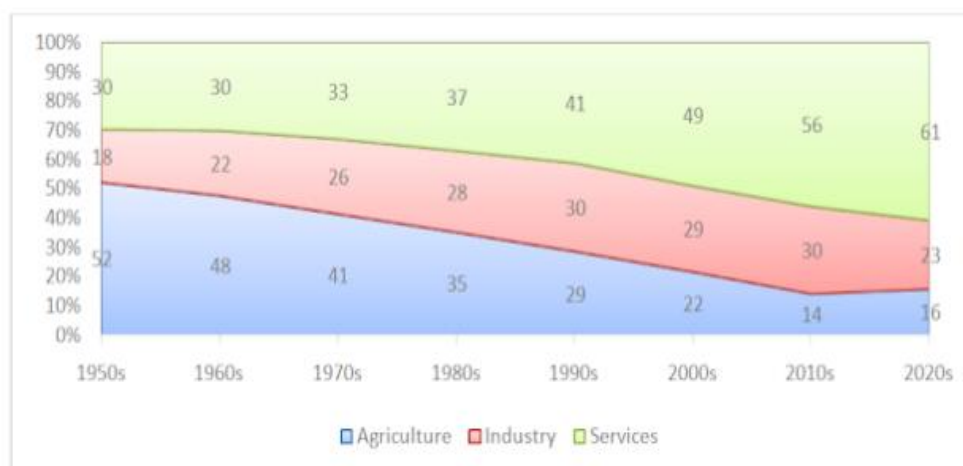


Fig. 1. Per cent share of Indian economic sectors to total GDP (1950 – 2020)

Source: Balwant Singh Mehta and Arjun Kumar, IMPRI, New Delhi

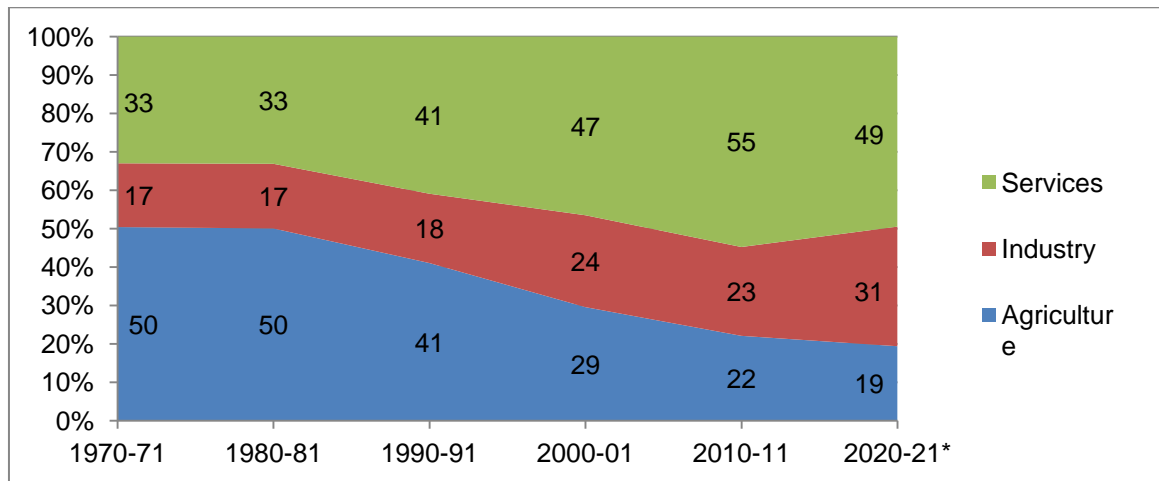


Fig. 2. Per cent share of economic sectors to total GDP of Andhra Pradesh (1970 – 2020*)

Note: * includes Telangana state data (2013 – 14 to 2020 – 21)

Source: Directorate of Economics & Statistics, DES, Government of Andhra Pradesh and Telangana

study focuses on the structural changes of Andhra Pradesh state economy with special reference to primary sector (agriculture and allied). Andhra Pradesh state is majorly agrarian based economy. Major river streams, lakes and canal systems bless the state in providing irrigation and electricity facilities [7].

Over the decades, the state has gone through structural changes as like all India scenario. During 1970's, half of the state's NDP was contributed by agriculture sector followed by services (33 per cent) and industries (17 per cent). Over the development of the state through Green revolution, primary sector continued to contribute half of the state's income even during early 1980's. After 1980's, i.e. from 1990 - 2010, the share of agriculture sector to state's income has declined by 19 per cent change but with improvement in industrial and service sectors 5 per cent and 14 per cent respectively. At present, contribution of agriculture and allied to the state economy stood at just 19 per cent, with a noticeable improvement in industrial sector by 31 per cent and services (most affected sector due to COVID – 19 pandemic) by 49 per cent (Fig. 2).

The inherent sub-sectoral structural changes in primary sector may contribute to overall sectoral changes and its contribution to the state's economy. To study the inherent sub-sectoral changes of the primary sector with respect to cropping pattern shifts and irrigational shifts is felt needful for the present study, so objectives of the present study are;

- i. To study the structural changes in Andhra Pradesh state's economy.

- ii. To study the structural changes in irrigation scenario of the state and
- iii. To study the shifts in area under cropping pattern and area under irrigation of principal crops

2. METHODOLOGY

The study is purely drawn with the help of secondary data. The data sources are obtained from various issues of statistical abstracts published from Directorate of Economics and Statistics (DES) of Government of Andhra Pradesh and Government of Telangana. The study covers the status of state's economy; with special reference to changes in subsectors (agriculture and irrigation) of primary sector for past 50 years i.e. 1970 – 2020 timeline. Triennium averages are calculated to overcome year-on-year effects for calculating area under irrigation water sources, cropping pattern and proportion of area irrigated under principal crops to total cropped area. To neutralize the variations in the statistics, after 2012 – 13 i.e. from 2013 – 14 to 2020 – 21, Telangana state data has been merged with the exiting Andhra Pradesh* state data to draw conclusions.

To analyses the trends in state's irrigation water sources over five decades, compound annual growth rate has been estimated using log-linear functional form [8].

* Bifurcation of existing Andhra Pradesh into Telangana and residuary Andhra Pradesh states under Andhra Pradesh Reorganization Act, No. 6, 2014.

$$\ln Y_t = a + bt \quad (1)$$

Where,

Y= Dependent variable (Irrigation water source)

a= intercept

b= Slope and

t= Time

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

Conventional analysis with averages and percentages is calculated to draw inferences on the structural changes in the agriculture and irrigation subsectors and their consequent impact on state's economy.

3. RESULTS AND DISCUSSION

3.1 Structural Shifts in State's Economy

The economy of Andhra Pradesh primarily depends on agriculture, providing employment for nearly 60 per cent of population in the state (Socio-economic survey, 2020 – 21, Govt. of Andhra Pradesh). More than 30 per cent of the state's income is contributed from primary sector.

The economy of Andhra Pradesh can be classified under 3 sectors that contribute for the state income (CSO methodology) viz. Primary sector (agriculture sector), secondary sector (industrial sector) and tertiary sector (service sector). The primary sector consists of agriculture and allied activities like agriculture and livestock, fisheries and forestry and logging. Secondary sector is industrial sector with sub activities like mining and quarrying, registered manufacturing, unregistered manufacturing, constructions, electricity, gas and water supply. The tertiary sector is service sector covering trade, hotels and restaurants, railways, transport, other means of communication, banking and insurance, real-estate, business services, ownership of dwelling, public administration and other services (Table 1).

Over the five decades, a continuous increase in population with a decline in share of primary sector to the state income is noticed. Though 60 per cent of population in the state is employed in primary sector, service sector contributes to the highest state income of 49.46 per cent, followed by secondary and primary sectors (Table 1). With consistent improvement in manufacturing sub sector in both the states, the secondary sector has attained second largest contributor to the economy by 31.13 per cent.

The contribution of primary sector over the decades declined enormously from 50.42 per cent to 15.34 per cent, while service sector and industrial sector progressed with increase in shares to total income from 32.97 per cent to 49.46 per cent and 16.6 per cent to 31.13 per cent respectively. As the contribution of agriculture and livestock has reported a declining trend, the fisheries compensated it with increasing share over the decades in the primary sector. While it is evident from Table 1, the contribution from forestry and logging found to be very meager (0.81 per cent to 0.31 per cent)

Registered manufacturing out lies the other subsectors contribution in secondary sector. Over the years, an increasing large scale and small scale manufacturing units helped the subsector to grow at a faster rate. Electricity, gas and water supply found to be prominent subsector (4.35 per cent) after registered manufacturing followed by construction and mining and quarrying subsectors. However, due to migration of labour due to COVID – 19 pandemic brought all the construction activities at a stake (Table 1).

The visibly worst hit sector due to COVID – 19 pandemic is services to the nation's economy (Economic Survey 2021 – 22, GOI). Stand still situation of the nation has brought a huge downfall to the economy, mainly to the contactable services and activities. Hotels, trade, transportation, constructions, banking services etc. faced decline during the pandemic. As a result the share of service sector has declined by -5.3 per cent change in the state (Table 1).

The shift of state's economy from primary sector to tertiary sector made an impact on per capita income levels of the state to progress from Rs. 286 to Rs. 129690 over five decades with increasing population in both the states. The highest share of service sector to the state income due to lower productivity of primary sector is also in consonance with all India scenario (Table 1).

3.2 Structural Shifts in State's Irrigation Scenario

Irrigation is the key focus area of water sector restructuring the state of any economy. Agriculture is driven by the key input called irrigation water. Structural changes in irrigation sources will bring about changes in cropping pattern adoption and so by the share of income

Table 1. Share of state income by industry of origin in Andhra Pradesh (NSDP at constant prices)

Sl. No	Sector	1970-71	1980-81	1990-91	2000-01	2010-11	2020-21*
1	Agriculture & livestock	48.58	48.60	39.54	26.47	18.41	15.34
2	Fisheries	1.03	1.07	0.84	2.12	2.40	3.70
3	Forestry	0.81	0.40	0.68	0.99	1.30	0.37
I	Agriculture sector (Subtotal 1-3)	50.42	50.07	41.07	29.58	22.11	19.41
4	Mining & Quarrying	0.76	0.92	0.90	2.01	2.41	2.86
5	Registered manufacturing	4.36	5.79	7.22	8.46	7.21	20.67
6	Unregistered manufacturing	5.69	5.06	4.14	5.07	2.79	
7	Construction	5.23	3.70	4.97	5.66	9.63	3.25
8	Electricity, gas...	0.55	1.36	0.81	2.72	1.10	4.35
II	Industry sector (Subtotal 4-8)	16.60	16.83	18.05	23.92	23.13	31.13
9	Transport, communication...	5.04	4.11	0.63	1.95	2.62	1.55
10	Railways	1.76	1.78	0.55	1.38	0.90	0.42
11	Transport by other means	2.22	0.57	3.21	2.83	5.14	4.97
12	Trade, hotel...	10.87	11.98	16.65	14.32	15.06	12.23
13	Banking & insurance	0.81	2.37	5.76	5.39	7.35	5.43
14	Real estate, business services...	3.14	3.04	4.46	6.46	11.60	13.42
15	Public administration	3.04	4.46	4.39	4.61	3.55	3.24
16	Other services	6.09	4.80	5.25	9.56	8.53	8.21
III	Services sector (Subtotal 9-16)	32.97	33.11	40.91	46.50	54.76	49.46
IV	State income	100.00	100.00	100.00	100.00	100.00	100.00
V	Per capita income (Rs.)	285.8767	662.63	1810.33	9533.66	37566.33	129690
VI	Population ('000)	44333	49879	62707	75126	83644	89943

Note: Author's own estimates, * includes Telangana state's data (2013 – 2020)

Source: Directorate of Economics & Statistics, DES, Governments of Andhra Pradesh and Telangana

Table 2. Trends in irrigation and irrigation intensity of Andhra Pradesh

Particulars	TE 1970-71	TE 1980-81	TE 1990-91	TE 2000-01	TE 2010-11	TE 2020-21*	Andhra Pradesh 2020-21
Net irrigated area ('000 ha)	3073.32	3447.69	4282.81	4483.45	4021.44	5102.09	2870.10
Gross irrigated area ('000 ha)	3987.01	4080.09	5074.51	5870.08	6114.10	6934.76	3811.08
Net cropped area ('000 ha)	16470.04	10873.34	11042.49	10998.87	10681.97	10687.41	5948.89
Gross cropped area ('000 ha)	18827.09	12227.79	13200.34	13496.32	13634.24	13207.27	7330.08
Proportion of NIA in net sown area (per cent)	21.63	31.69	38.79	40.77	37.87	47.74	48.24
Proportion of GIA in gross sown area (per cent)	24.62	33.55	38.44	43.48	44.80	52.51	51.99
Irrigation intensity (per cent)	129.92	118.81	118.48	130.89	161.81	135.92	132.78

Note: NIA – Net Irrigated Area, GIA – Gross Irrigated Area, * includes Telangana state's data
Source: Directorate of Economics & Statistics, DES, Governments of Andhra Pradesh and Telangana

Table 3. Structural changes in sources of 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*	Andhra Pradesh 2020-21
Canals	1487.35 (48.39)	1671.19 (48.47)	1876.05 (43.80)	1639.31 (36.56)	1515.22 (37.68)	1717.11 (33.65)	1338.11 (46.63)
Tanks	985.45 (32.07)	929.66 (26.97)	1032.57 (24.11)	729.57 (16.27)	463.92 (11.54)	502.37 (9.85)	272.53 (9.49)
Groundwater	492.87 (16.03)	747.23 (21.67)	1214.96 (28.37)	1916.93 (42.76)	1890.93 (47.02)	2676.77 (52.47)	1145.39 (39.90)
Others	107.65 (3.51)	99.61 (2.89)	159.23 (3.72)	197.62 (4.41)	151.37 (3.76)	205.83 (4.03)	114.08 (3.98)
Net irrigated area	3073.32 (100.00)	3447.69 (100.00)	4282.81 (100.00)	4483.45 (100.00)	4021.44 (100.00)	5102.09 (100.00)	2870.11 (100.00)

Note: * includes Telangana state's data (2013 – 14 to 2020 – 21)
Source: Various issues of statistical abstracts, DES, Governments of Andhra Pradesh and Telangana

from agriculture. The need for study of irrigation in the state has aroused due to constant decline in contribution from agriculture.

The trends in total net irrigated area and gross irrigated area in the state have shown an upward progress over the decades (Table 2). The proportion of net irrigated area to net sown area shown an improvement together by 52.51 per cent (TE 2020-21*) compared to previous trienniums. With improvements in proportions of total irrigated area to cropped area, simultaneous improvement in the irrigation intensity of the state (ratio of gross irrigated area to net irrigated area) is noticed i.e. 129.92 per cent to 135.92 per cent. The results are in conformity with the study conducted by Geetha Mohan [9]. Though total net cropped area stood more or less same, with the implementation of several irrigation development programs in the state, the proportion of land brought under total net irrigated area has been improved over the decades which is a positive sign of the state's agricultural scenario (Fig. 3).

The structure of sources of irrigation of the state comprises of canals, tanks, tubewells, borewells, otherwells and other sources (micro irrigation). From the major river streams of Godavrai, Krishna, Penna, Nagavali, Vamshadhara and other minor rivers, canals continue to serve several irrigation needs of the state. The peninsular plateau region with largest area under tank irrigation of 5.02 million hectares followed by Tamil Nadu state.

Over the past, considerable structural changes in irrigation sources has taken place in state resulting in over extracion of groundwater resources through wells. The major canal and tank irrigation structures has been substituted with well irrigation. A consistent decline in tank irrigation from 32.07 per cent to just 9.85 per cent of total net irrigated area and improvement of well irrigation from 16.03 per cent to 52.47 per cent is a major structural shift (Table 3).

Though canals continue to occupy the highest share of irrigation (Andhra Pradesh by 46.63 per cent), improvements in well irrigation with higher groundwater extraction is a huge structural shift in south-eastern coastal state (Table 3). Over the decades (1970 – 2020), the contribution of each source of irrigation accounted for 48 – 34 per cent (canals), 34 - 10 per cent (tanks), 15 - 54 per cent (groundwater) and 4 per cent by other sources. These structural shifts represent improvement of irrigation capacity in the state with over extraction of groundwater sources and poor maintainence and rehabilitation of ecofriendly tank water structures (Table 3).

In continuity with the study of structural shifts of irrigation sources in the state, the growth pattern of each source of irrigation under 2 phases of 25 years each is studied as under Table 4. Significant decline in irrigation water structures with negative growth is recorded for canals and tanks along with the overall net cropped area of the state.

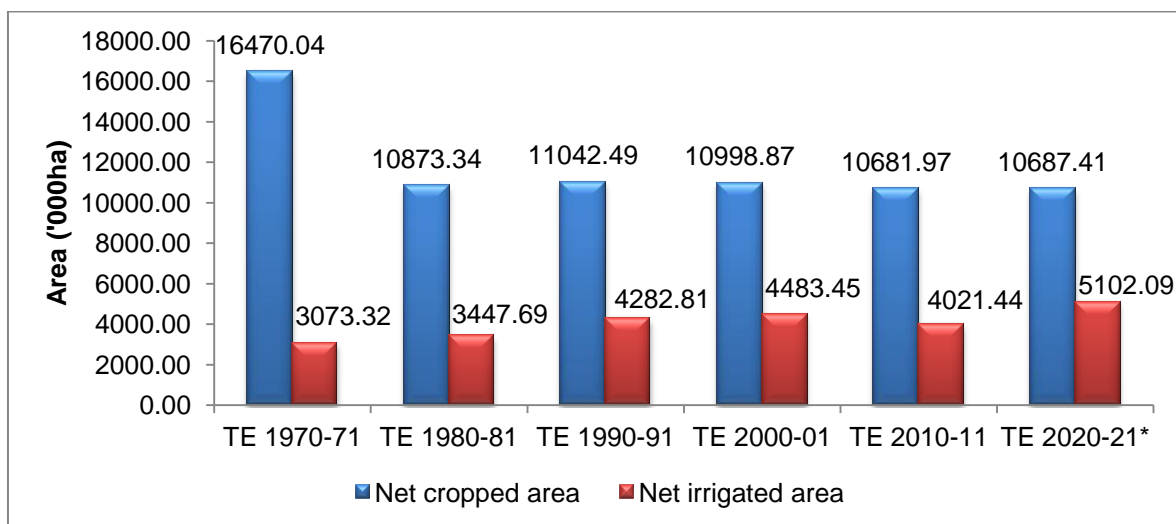


Fig. 3. Trends in relationship between net cropped area and net irrigated area of Andhra Pradesh

Note: * includes Telangana state data (2013 – 14 to 2020 – 21)

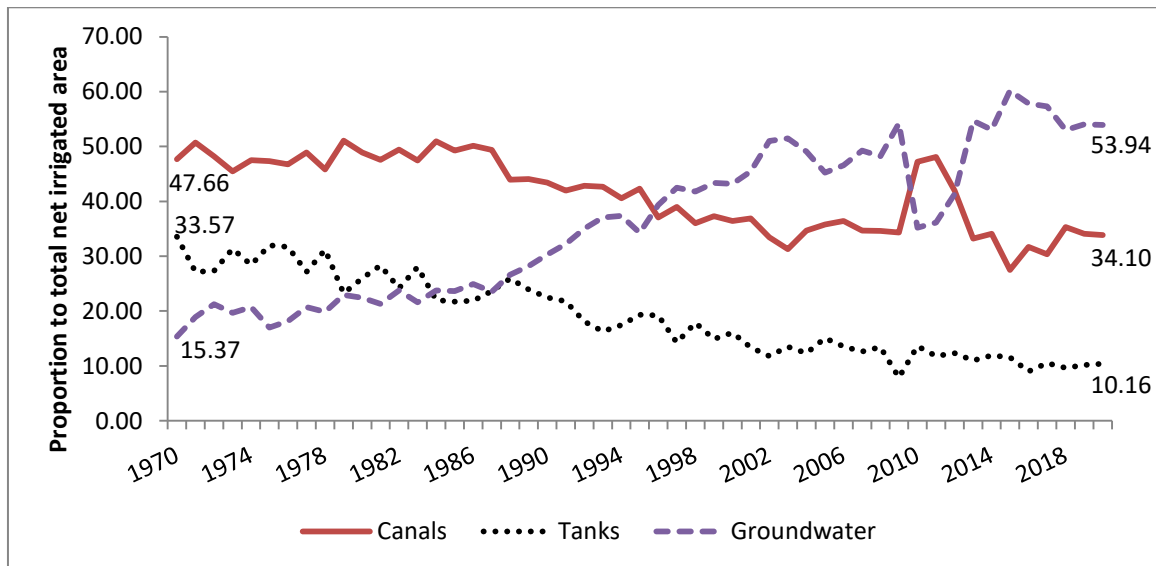


Fig. 4. Structural shifts in per cent share of irrigation sources to total net irrigated area in Andhra Pradesh (1970 – 2020)

Source: Various issues of statistical abstracts, DES, Governments of Andhra Pradesh and Telangana

Table 4. Compound annual growth rate in irrigation sources of Andhra Pradesh (1971 - 2020)

Source	I – Phase (1971 – 1995)	II – Phase (1996 – 2020*)	Overall*
Canals	0.63***	0.21	-0.29**
Tanks	-1.07**	-1.36	-1.94***
Groundwater	4.25***	1.66**	3.22***
Others	2.50***	-4.96***	-0.54
Net irrigated area	1.23***	0.62	0.65***
Net cropped area	-0.29***	0.16	-0.07*

Note: *, ** and *** indicate significance at 10 per cent, 5 per cent and 1 per cent level of significance

Groundwater recorded highest significant positive growth in both the phases with 4.25 per cent, 1.66 per cent and an overall of 3.22 per cent respectively. Though several tank rehabilitation programs were introduced in the state, the growth rate of tank irrigation structures continue to decline till to the present (-1.94 per cent). The results are in conformity with the study conducted by Kiran Kumara and Shiv Kumar [10].

This represents improvement in technologies for well irrigation and amount of groundwater extraction in the state. The significant decline in growth of net cropped area (-0.07 per cent coupled with significant growth in net irrigated area (0.65 per cent) over the decades is found to be revealing phenomenon of the state.

3.3 Structural Shifts in Area under Cropping Pattern and Area under Irrigation of Principal Crops

Structural changes in state’s irrigation sources posed a major shift in area under irrigation and

cropping pattern of principal crops in the state. The area under cultivation of commercial crops gained prominence in the state next to rice cultivation. Though food grains are comparatively less water consuming, commercial crops cultivation with major extraction of groundwater resources and canals systems is the current scenario of the state (Tables 3 and 5).

Over the decades to the present date, rice continued to occupy the highest area under cultivation (46 per cent i.e. 42.96 lakh ha) among all other crops in the rice bowl state of India. A comparison of structural changes in cropping pattern after thirty and twenty years from TE 1970-71 portrays that and area under coarse cereals (Jowar and Bajra) has lost the prominence in the state (Fig. 5). Area under cultivation of commercial crops like cotton has improved to 12 per cent (TE 2000-01) and 26 per cent (TE 2020-21*), may be due to high profitability of the crop compared to other cash crops of the state. Area under total food crops continued to outweigh the area under non-food

crops (condiments, spices, drugs and narcotics etc.) over the decades. Though gross cropped area of the state was found to decrease, the total production found to increase (Fig. 5). The results are in conformity with Venkatesh and Sen [11].

The structural shifts from coarse cereals to commercial crops and high area under rice cultivation under canal and groundwater irrigation sources poses challenge to withstand risk and equity concerns to small and marginal farmers. Though state is blessed with major river streams which help to sustain groundwater and canal irrigation systems, less water consuming and nutritious crops are being substituted with commercial crops [12,13]. Proper maintenance of community tank irrigation structures which aid in

production of cost effective, less water requiring coarse cereals may help to retain the ecological agriculture in the state [14].

The highest irrigated cropped area to total cropped area is occupied by rice crop by 98 per cent during TE 2020-21. Krishna-Godavari river basin being the rice-bowl of India cultivates highest rice cropping pattern systems under canal irrigation. Though wheat found to be negligible under cultivation, most of the cultivated land has turned out to be irrigated cropped area (Table 5). The major cereals & millets gained most of the cultivated area under irrigation over the decades and stand out to be the major food crops section under irrigation by 88 per cent (Figs. 6 and 7).

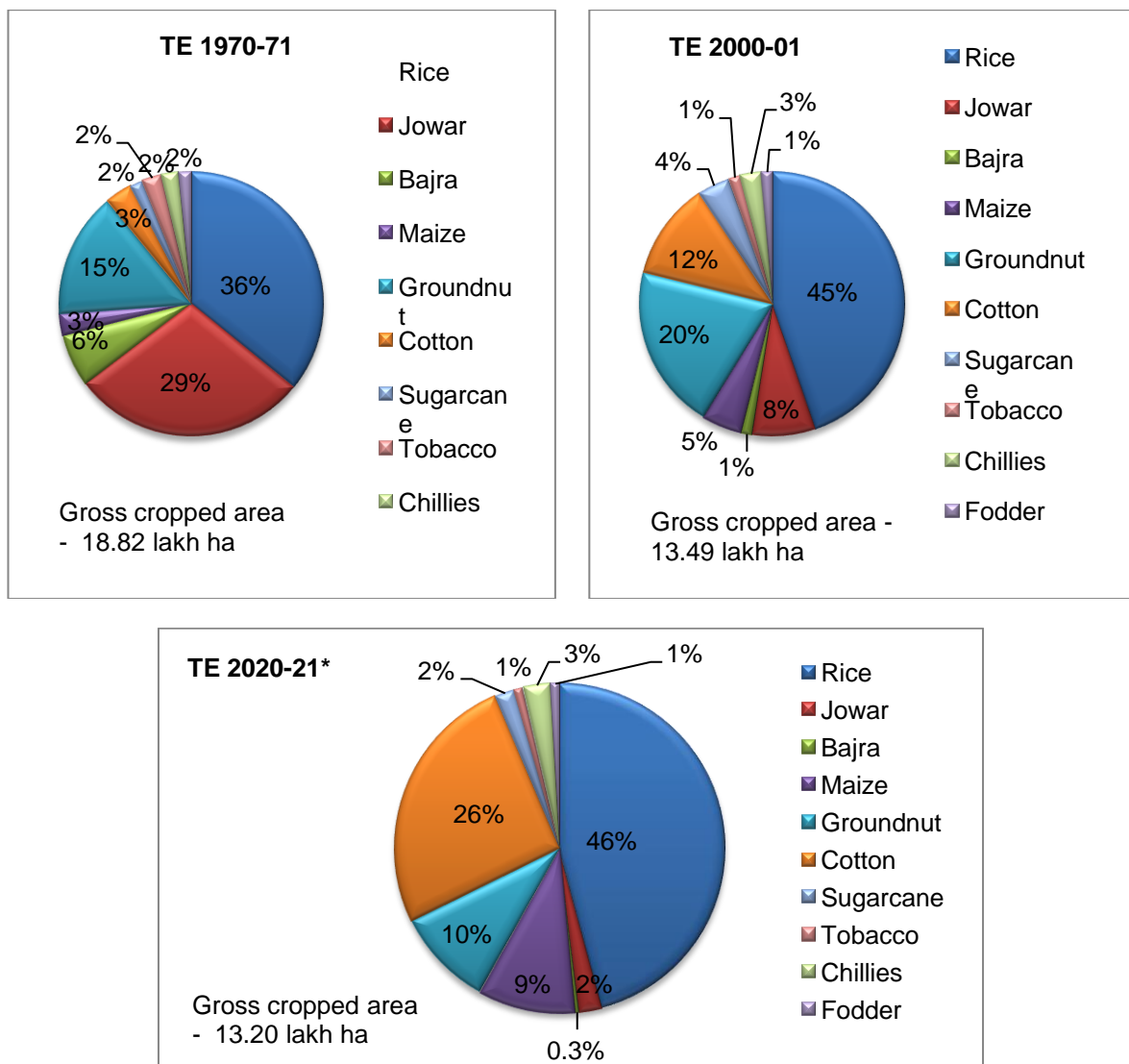


Fig. 5. Per cent share of area under cultivation of principal crops in the state (1970-2020)
 Source: Various issues of statistical abstracts, DES, Governments of Andhra Pradesh and Telangana

Table 5. Structural shifts in per cent irrigated to cropped area under principal crops in Andhra Pradesh ('000 ha)

Crops	TE 1970-71	TE 1980-81	TE 1990-91	TE 2000-01	TE 2010-11	TE 2020-21*	Andhra Pradesh 2020-21
Rice	94.27	94.25	95.19	95.62	97.13	98.07	97.26
Wheat	38.71	64.70	77.38	76.56	89.69	99.25	77.70
Jowar	1.48	0.79	1.61	3.13	9.17	34.28	41.97
Bajra	11.10	11.12	12.21	18.10	34.92	46.21	30.55
Maize	20.47	23.30	28.40	32.34	47.70	48.54	73.37
Groundnut	13.66	16.90	19.64	17.58	19.44	29.03	16.79
Cotton	3.55	6.06	13.65	17.81	17.14	14.93	17.27
Sugarcane	97.93	98.38	82.12	62.42	57.75	78.05	66.00
Tobacco	10.27	17.33	31.79	28.35	25.46	37.45	36.27
Chillies	42.31	45.54	69.17	64.73	83.73	92.90	94.17
Fodder crops	8.43	7.49	6.52	5.68	24.75	50.61	27.15
Total cereals & millets	42.94	48.75	63.45	74.55	83.13	87.90	92.91
Total pulses	0.46	0.18	1.17	0.97	2.03	4.79	2.99
Total oilseeds	10.39	13.73	16.16	16.99	22.01	35.24	29.57
Total food crops	36.86	41.57	51.87	57.36	19.76	67.27	63.51
Total non-food crops	9.28	12.21	16.58	17.12	33.04	22.08	22.93

Source: Directorate of Economics & Statistics, DES, Governments of Andhra Pradesh and Telangana

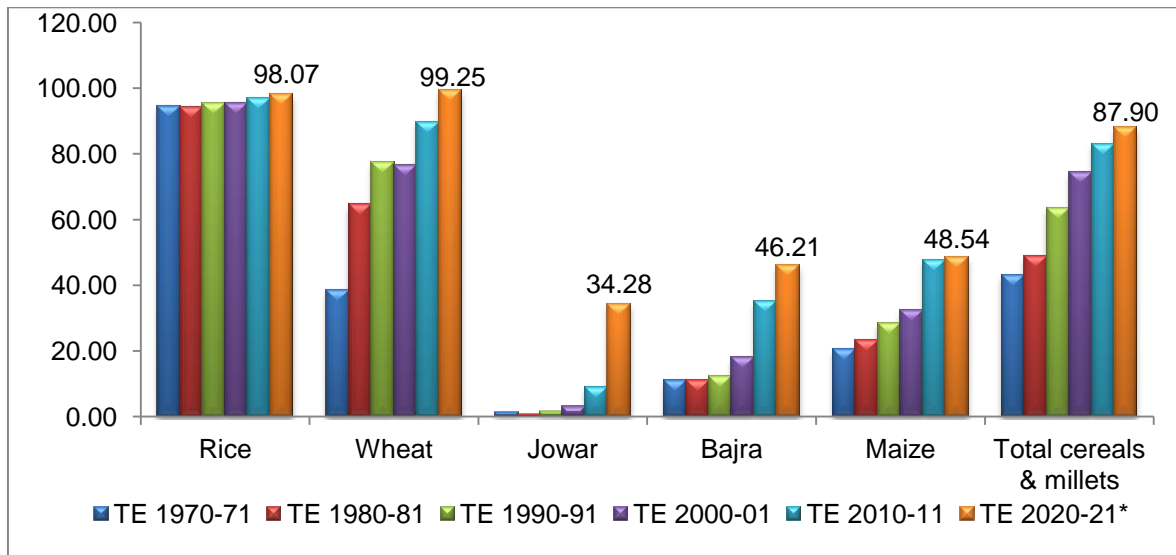


Fig. 6. Percentage share of irrigated area under major cereals and millets in the state
 Source: Various issues of statistical abstracts, DES, Governments of Andhra Pradesh and Telangana

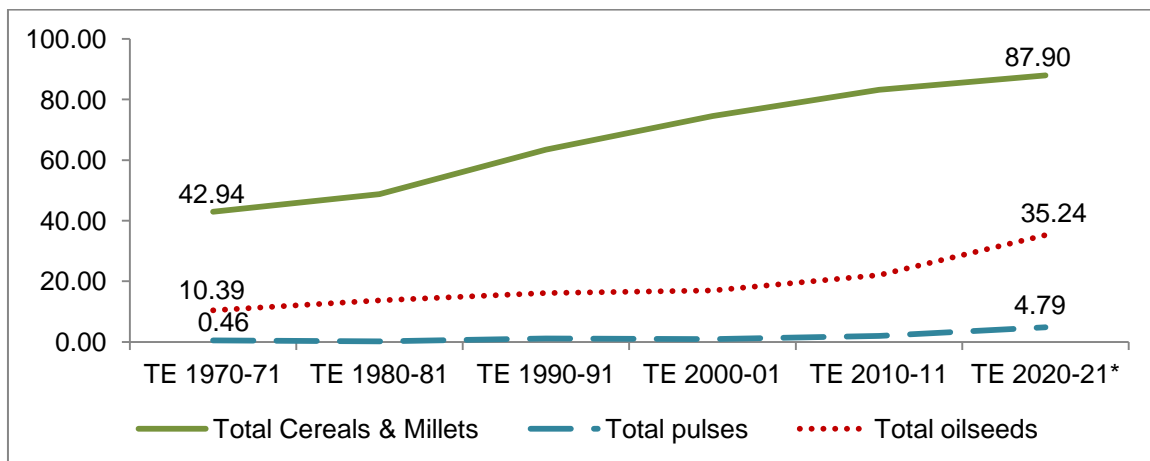


Fig. 7. Percentage share in irrigated cropped area total cropped area of principal crops
 Source: Various issues of statistical abstracts, DES, Governments of Andhra Pradesh and Telangana

The area under irrigation to cropped area has been improved for cereals and millets, pulses and oilseeds over the time (Table 5 and Fig. 7). Though cotton occupied higher area under cultivation than sugarcane, the irrigated cropped area is less compared to sugarcane, indicates less water requirement and high profitability of the crop. The state being major producer of chillies turned 93 per cent of total cropped area under irrigated conditions during TE 2020-21*. The prominence of livestock sector in the state is visible with increase in irrigated area under fodder crops over the time. Total food and non-food crops accounted for 67.27 per cent and 22.08 per cent of total cropped area under irrigation. The results are in conformity with

studies conducted by Mouzam et al. [15] and Geetha [16].

4. CONCLUSION

From the view of whole economy to individual sub-sectors, the state is undergoing major structural shifts time to time. Contribution from the agrarian sector has taken a shift to service sector with growing industrial sector in the agrarian state. Due to lower productivity from agriculture sector, the contribution to total state income has reduced drastically over the years. Though agriculture sector absorbs more than 60 per cent workforce, the productivity continued to be lower. The shifts arising from agriculture and

allied subsectors (irrigation) have impetus effect on net irrigated and net cropped areas. Overall improvement in net irrigated area is observed by 1.6 times (3.07 million ha to 5.1 million ha) with simultaneous growth in canal and well irrigation sources.

Degradation of surface water irrigation sources (tank irrigation) and over extraction of groundwater resources through wells brought a major structural shift in primary sector forcing farmer growers to change cropping patterns. Fivefold increase (4.92 million ha to 26.76 million ha) in groundwater sources is compensated with twofold reduction (9.85 million ha to 5.02 million ha) in tank water sources which poses threat to small and marginal farmers. Canal coupled with wells is the current irrigation scenario of the state.

These shifts in irrigation sources had impetus effects on cropping pattern shifts too. Mono-cropping or double cropping situations has aroused where paddy being the major crop or followed by commercial crops or pulses. Coarse cereals like jowar, bajra had almost lost their inclusion in cropping systems. More than 85 per cent of irrigated cropped area is under cereals and millets, the top being paddy (98 per cent) and maize (48 per cent). Over the decades, wheat gained significant proportion of area under irrigation (though cropped area is less).

5. POLICY IMPLICATIONS

Pressurized irrigation technologies should be promoted to maintain sustainability of ecofriendly tank irrigation structures. Efforts to include less water consuming coarse cereals should be adopted for maintaining nutritional security among small and marginal households. Promulgation of reclamation measures to attain ecological balance between groundwater and surface water irrigation sources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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