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Research Article

SITUATION ANALYSIS OF WATER RESOURCES IN TAMIL NADU

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Abstract: Water is an important natural resource for agricultural production. In Tamil Nadu about 95 percent of the surface water resources have already been utilised and the groundwater is being over-utilised. This paper examined the changing sources of irrigation in the state. Rainfall being one of the major sources of replenishment, the paper also studied the impact of rainfall in area irrigated by major sources and also in recharging groundwater table. The share of tanks and canals as source of irrigation in the state has been declined to 15 percent and 23.53 percent during 2010s. The net irrigated area by tanks and canals have denigrated to a negative overall growth rate of -1.419 and -0.436. The share of wells has been increased to 62 percent in 2010s. The net irrigated area by wells alone have achieved commendable growth rate of 1.512. The relative projected share of various sources of irrigation during 2025 and 2050 is quite the same as that of relative share in 2015. Markov Chain analysis has found that only 10.70 percent of area irrigated by tanks will change to well irrigation during the time period considered. Among the major sources of irrigation, Well irrigation is highly influenced by rainfall. The measure of standard deviation for actual rainfall affirms its erratic nature which not only deviates in quantity but also in distribution through the year. High variation in downpour was found in winter showers. Rainfall, highly influences groundwater table as the percentage of blocks under safe category has followed the same pattern as rainfall received. The water storage capacity has to be developed in order to recharge the groundwater thru rainfall. Prior to planning for sustainable crop production, the stock on available data of water resources have to be assessed and accessed to enable a prudent effort.

Keywords: Net irrigated area, Markov Chain analysis, Water resources

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Introduction

Water provides goods and services that are utilized by agriculture, industry and households. Water is an important natural resource for agricultural production. Without water for irrigation, even the successes of Green Revolution would not have been achieved despite availability of all the other resources [1]. Tamil Nadu, one of the peninsular states of India, comprises only 2.50 percent of the water resources of the country. Agriculture is the principal source of livelihood for more than 40 percent of the population of the State [2]. More than 95 percent of the surface water and 80 percent of the ground water have already been put into use [3]. Though the state has achieved significant progress in agriculture sector, marginalization of land holdings, high variability in rainfall distribution, inadequate capital formation by the public sector, declining public investment in agriculture, declining net area sown, overexploitation of ground water and inadequate storage and post harvest facilities affect the agricultural performance in the state [4]. Canals, wells and tanks are the major sources of irrigation in Tamil Nadu apart from other supplementing sources such as springs, jungle streams etc. Wells and tanks depend upon rainfall for recharge. Eventually, the area irrigated by tanks and well to some extant are supposedly influenced by quantity of actual rainfall. The irrigation intensity in Tamil Nadu during 2015-16 was 126 percentage. The overall growth rate has shown a positive but not laudable increase in net irrigated area (NIA) in the state. Especially during the period 2011-2016 NIA have attained a negative growth. Thus, the impact of rainfall on the capability of various sources of irrigation in area irrigated has to studied as it puts into question the sustainability of irrigated agriculture in the state. It has to be stated that 95 percent of the surface water resources in the state have already been utilised [3].

There has been a massive expansion of groundwater irrigation through wells [5]. In this context, the study examines the status of irrigation in Tamil Nadu with the following objectives; 1. To study the influence of various sources of irrigation in area irrigated over the years; 2. To analyse the magnitude of shift in area irrigated by various sources of irrigation over the years; and 3. To understand the trend in rainfall and its influence on canal, well, tank irrigation and groundwater recharge.

Methodology

The statistics of monthly rainfall over the years from 1970 was collected from various issues of Season and Crop Report of Tamil Nadu. The statistical measures of spread such as mean, standard deviation and variance were used to understand the extant of vagaries of rainfall. The compound growth rate was also employed to study the decadal change in net area irrigated by various sources. The rainfall-irrigated area regression function was used to study the impact of rainfall on various sources of irrigation such as canals, tanks and wells. The regression function was specific to every source of irrigation. In the study, Markov Chain Analysis was used to study the probabilities of change between various sources of irrigation and to project the relative share of the same in future. As Markov chain is a stochastic model whose states, discrete or continuous, are governed by a transition probability. A discrete-time stochastic Markov Chain process could be depicted as,

$$P\,[X_j,\, t_{+1}: X_i,\, t,\, X_{i-1},\, t_{-1},\, \dots,\, X_o, t_o] = P\,[X_j,\, t_{+1}:$$

The main basic assumption in Markov Chain is that the probability distribution of the state X_j at time t_{+1} depends upon the state X_i at time t alone and does not depend upon the states at time t_{-1} or before.

Table-1 Decadal changes in rainfall in Tamil Nadu

Year	1970s	1980s	1990s	2000s	2010s	Overall
South-West						
Mean	317.15	317.47	314.52	307.66	290.60	309.48
Standard Deviation	58.64	69.45	70.42	59.63	40.66	59.76
Coefficient of Variation (%)	18.49	21.88	22.39	19.38	13.99	19.23
North-East						
Mean	472.23	372.95	515.99	514.40	401.87	455.49
Standard Deviation	154.99	91.63	158.10	130.70	126.21	132.33
Coefficient of Variation (%)	32.82	24.57	30.64	25.41	31.41	28.97
Winter						
Mean	15.83	40.57	26.14	23.36	19.27	25.03
Standard Deviation	18.19	58.93	34.32	20.85	13.37	29.13
Coefficient of Variation (%)	114.88	145.25	131.29	89.26	69.38	110.01
Summer						
Mean	112.89	111.70	102.46	163.90	111.87	120.56
Standard Deviation	32.06	38.79	42.98	69.10	39.28	44.44
Coefficient of Variation (%)	28.40	34.72	41.94	42.16	35.12	36.47
Annual						
Mean	918.10	842.69	959.11	1009.32	823.60	910.56
Standard Deviation	156.81	178.47	168.12	180.24	101.12	156.95
Coefficient of Variation (%)	17.08	21.18	17.53	17.86	12.28	17.24

Markov Chain analysis was used to study the irrigation system adoptions and changes [6]; simulating rainfall pattern [7-9]; predicting future market prices [10]; changing cropping pattern, [11, 12]; land use changes [13-15]. Dlamini *et.al.*, (2015) have used Markov Chain analysis to simulate the daily rainfall by developing a Stochastic Rainfall Generator Model [16]. Yoo (2016) have used Markov Chain analysis to decompose monthly rainfall to daily rainfall in China [17]. Another basic assumption of Markov Chain Analysis is that the total should be constant. In the study, it is the total net irrigated area which would be shared among various states *i.e.* sources of irrigation. As the total net irrigated area (NIA) could not be kept constant, the absolute values of NIA could not be used for the analysis. Instead, relative values of area irrigated by various sources of irrigation were taken for analysis. The assumption for transition probabilities was that there would be no new irrigation management inventions or new source of irrigation or major droughts or significant changes in government propagandas. Any of such could influence the predictions projected by the analysis.

The 1st order Markov Chain transition probability matrix could be expressed as,

$$P_{ij} = \begin{bmatrix} P_{11}\ P_{12}\ \ldots\ \ldots .\ P_{1m} \\ P_{21} P_{22}\ \ldots\ \ldots .\ P_{2m} \\ \vdots \\ P_{n1} P_{n2}\ \ldots\ \ldots .\ P_{nm} \end{bmatrix}$$

where, P_{ij} is the probability that an area under the state 'i' during time t changes into the state 'j' during t_{+1} and 'n' is the number of states.

Results and Discussion

Rainfall

Rainfall being the major source of water recharges the surface water sources and seeps into the ground to reach and replenish the underground aquifers. The average annual rainfall is 930-960 mm throughout Tamil Nadu. The state receives around 50 percent of rainfall from North-east monsoon, 34 percent from South-West monsoon, 13 percent during Summer and three percent during Winter. Rainfall is characterised by many upswings and downswings [Fig-1]. Some years were relished with good downpour (*e.g.* 2005-06, 2007-08) and some years were deprived with scanty rainfall (*e.g.* 2006-07, 2009-10). The erratic nature of rainfall could be studied from the table below. [Table-1] presents the decadal changes in four seasons of rainfall in the state. The decadal mean, standard deviation and co-efficient of variation are computed for the four seasons of rainfall. The agricultural production and productivity of crops mainly depend on the timely onset, quantum and spread of rainfall through the year. The north east (NE) monsoon provides the maximum rainfall to the state. The standard deviation was highest in NE monsoon followed by south-west monsoon. Such deviation had largely influenced the choice of crop, crop area, production and eventually price of agricultural commodities. High variation in downpour was found in winter showers followed by summer showers. The overall mean, standard deviation and variance in annual rainfall were 910.56mm, 156.95mm and 17.24 percent, respectively. The annual rainfall was ranging from 823.60mm during 2011-2015 and 1009.32mm during 2001-2010. A planned reserve of excess rainfall could buffer during the years with scarcity. Many farmers are confident about cultivation because of the Anicut area built for rain water storage [4].

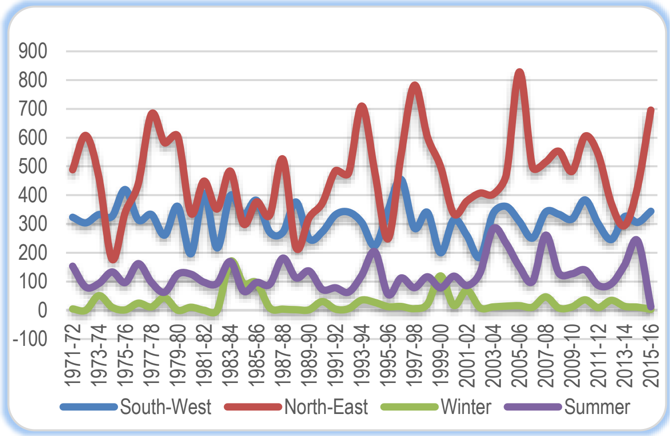


Fig-1 Annual Rainfall in Tamil Nadu 1971-2016 (mm

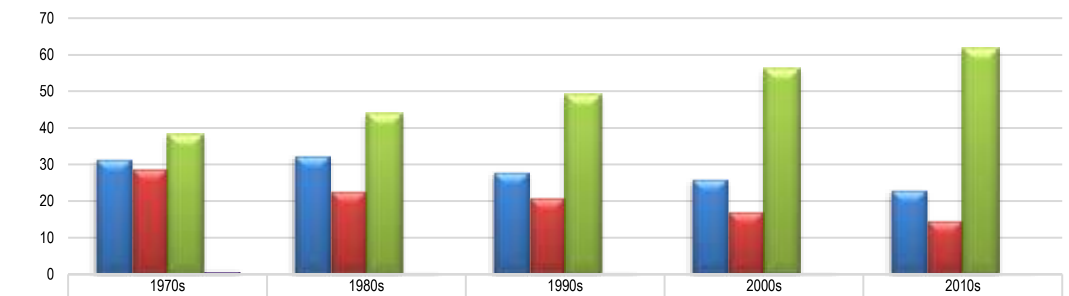
Source: Author's own estimation based on various issues of Season and Crop Report, Government of Tamil Nadu.

Trend in Sources of Irrigation

The net area irrigated by various sources of irrigation over the years is presented in [Table-2]. The net area irrigated by Tanks in 1970's was 894.76 thousand ha (31.62 percent) which has reduced to 666.10 thousand ha (22.95 percent). The net area irrigated by Canals in 1970's was 818.48 thousand ha (28.92 percent) which has drastically reduced to 426.24 thousand ha (14.68 percent). The net area irrigated by Wells in 1970's was 1083.09 thousand ha (38.27 percent) which has increased to 1779.55 thousand ha (61.31 percent). The overall net area irrigated in Tamil Nadu was 2830 thousand ha in 1970's which has increased to 2902.71 thousand ha in 2010's. The increase in overall net area irrigated can be attributed to increase in the net area irrigated by wells in the state. The overall growth rate has shown a positive but not laudable increase in net irrigated area in the state. Especially during the period 2011-2016, the net irrigated area has attained a negative growth.

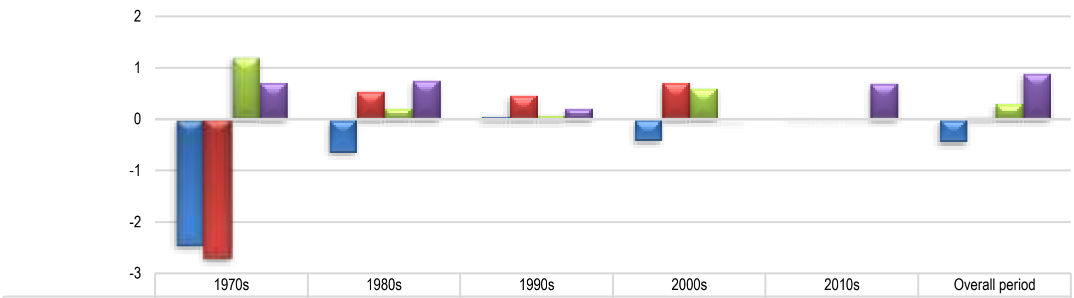
TANKS

In Tamil Nadu, tanks are the principal source of irrigation in many districts and they support 14 percent of total net irrigated area in the state. The share of tanks as source of irrigation in the state has been declined from around 29 percent in 1970s to 15 percent in 2010s [Fig-2].



	1970s	1980s	1990s	2000s	2010s
Canals	31.61	32.51	28.02	26.13	23.15
Tanks	28.92	22.87	21.04	17.26	14.81
Wells	38.26	43.93	49.20	56.22	61.85
Others	1.21	0.70	0.53	0.39	0.19

Fig-2 Share of Sources of Irrigation 1971-2016



	1970s	1980s	1990s	2000s	2010s	Overall period
No. of canals	-2.461	-0.632	0.083	-0.407	0.027	-0.436
Tanks-PWD (> 40 ha)	-2.71	0.56	0.469	0.723	0	0.053
Tanks-PU (< 40 ha)	1.216	0.219	0.088	0.606	0	0.309
No.of wells	0.719	0.762	0.219	-0.032	0.717	0.908

Fig-3 Growth Rate of Sources of Irrigation in Tamil Nadu (%)

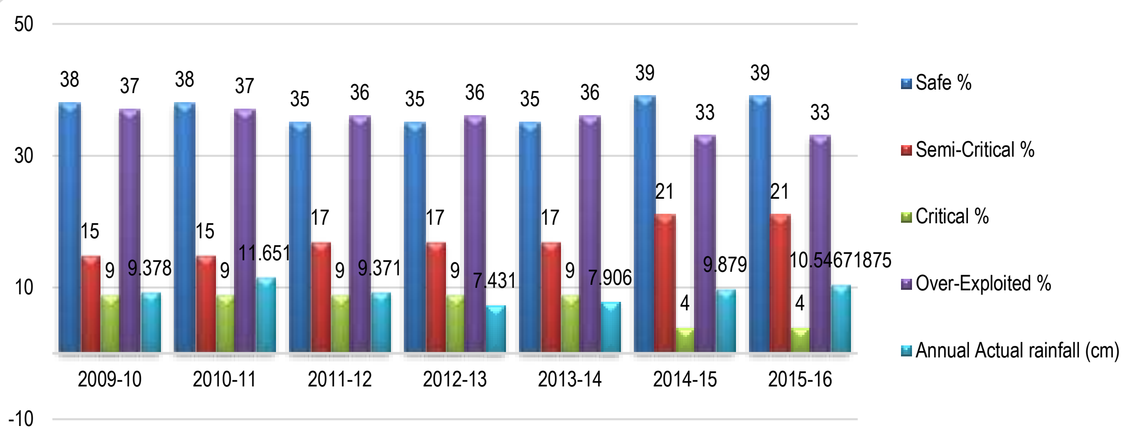


Fig-4 Ground Water-Categorisation in TN Vs Actual Rainfall 2009-2016

The number of tanks in the state has seen a significant decrease in the growth rate over the time from 1970s to present though there was a significant rise during 2000s [Fig-3]. Specially, PWD tanks' growth had hit a negative growth rate in 1970s and has attained an overall dismal growth rate of 0.053. The net irrigated area by tanks have denigrated to a negative overall growth rate of -1.419 and have achieved a disapprovingly negative growth rate during 2010s [Table-3]. Based on the TE 2016 in districts such as Kancheepuram and Pudukottai, more than 50 percent of NIA were irrigated by tanks. One major reason for the decline in collective tank irrigation management is the increase of private well irrigation systems [18, 19]. Tanks which are common property infrastructure have degraded into an open access resource because of encroachments, privatization and government appropriation [19].

Table-2 *Net Area Irrigated by Various Sources of Irrigation*

	1970s	1980s	1990s	2000s	2010s
Tanks	894.76	818.02	835.85	748.46	666.10
%	31.62	32.15	28.93	26.13	22.95
Canals	818.48	575.57	627.77	494.52	426.24
%	28.92	22.62	21.73	17.27	14.68
Wells	1083.09	1105.35	1467.72	1610.60	1779.55
%	38.27	43.45	50.80	56.23	61.31
Others	34.23	17.50	15.88	11.14	5.32
%	1.21	0.69	0.55	0.39	0.18
Total Net Area Irrigated	2830.00	2544.22	2889.23	2864.28	2902.71

Source: Season and Crop Report – Various issues, Government of Tamil Nadu.
Note: Area of tanks, canals, wells and others in '000 ha.

Table-3 *Growth Rate in Net Irrigated Area by Sources of Irrigation in Tamil Nadu (%)*

No. of sources / Year	1970s	1980s	1990s	2000s	2010s	Overall period
NIA	0.25	0.047	1.428	1.996	-0.489	0.21
Canals	-0.396	-0.884	-0.242	1.491	-0.839	-0.627
Tanks	-2.151	-1.911	0.363	2.272	-4.949	-1.419
Wells	2.567	1.961	2.936	2.227	0.879	1.512
Net cropped area	0.099	2.25	-0.875	0.366	-0.037	-0.519

WELLS

The share of wells as source of irrigation in the state has been increased from 38 percent in 1970s to 62 percent in 2010s [Fig-2]. Wells consists of open wells, tube wells, dug cum bore wells and filter point tube wells. Wells in the state have seen a tremendous increase in number with a growth rate of 0.908 over the time from 1970 to present albeit little lagging in growth in some decades 1990s and 2010s [Fig-3]. Dug wells were the main contributor to the growth of groundwater irrigation up till late 1990s. Tube-well irrigation seemed to be taking the place of dug wells in most regions. Heavy decline of water table have budged farmers to resort to competitive deepening of wells. Despite dismal growth in overall net irrigated area, the net irrigated area by wells alone have achieved commendable growth rate of 1.512 [Table-3]. Based on the TE 2016 districts such as Villupuram, Vellore, Thiruvannamalai, Salem, Namakkal, Dharmapuri, Krishnagiri, Perambalur, Nilgiris and Theni have more than 80 percent of net irrigated area through wells. The subsidised supply of power to agricultural pump sets were one of the reasons for wider adoption of well irrigation in the state [20].

CANALS

Cauvery delta is the most important canal system in Tamil Nadu. It should also be recorded that the timing and quantity of release of water from Mettur reservoir would impact on Kuruvai cultivation in Cauvery Delta with a ripple effect. The share of canals has declined from 31.61 percent in 1970s to 23.53 percent in 2010s [Fig-2]. The growth of canals has declined drastically and has attained an overall negative growth rate of -0.436 [Fig-3]. The reason might be due to increased dependence on wells. Based on the TE 2016 districts such as Thanjavur, Thiruvar and Nagapattinam Districts have more than 60 percent of their net irrigated area by canals. One important demerit of canal irrigation is the less water availability in the tail regions of canals when compared to head and middle regions which eventually causes yield variation [4].

Changing Sources of Irrigation

The results of Markov chain analysis provides the probabilities to change from one source of irrigation to other [Table-4]. The preliminary graphs have shown a remarkable decline in tank irrigation and increase in well irrigation. The probability of well irrigated areas to stay as well irrigated is high (0.971) i.e., 97.10 percent of wells irrigated area will remain irrigated by well itself. But the probability to change from canal to well irrigation is nil and from tank to well irrigation is less 0.107 i.e., only 10.70 percent of area irrigated by tanks will change to well irrigation during the time period considered. The relative projected share of various sources of irrigation during 2025 and 2050 is quite the same as that of relative share in 2015.

Table-4 *Transition probability of select sources of irrigation*

Sources of irrigation		Canals	Tanks	Wells	Others
Canal		0.577	0.423	0.000	0.000
Tanks		0.516	0.365	0.107	0.012
Wells		0.029	0.000	0.971	0.000
Others		0.000	0.484	0.000	0.516
2015 (%)		22.73	14.81	62.36	0.10
Projections (%)	2025	23.12	15.63	60.87	0.38
	2050	23.17	15.67	60.78	0.39

Influence of Rainfall on Irrigation

The distribution of rainfall over the state and also through the year matters for better utilisation of rainfall for irrigation. The anomalies of rainfall have the potential to cause undesirable effects on crop production and food security [21].

Table-5 *Rainfall - Irrigated Area Regression Results*

Regression	Dependent Variable	Independent Variable	F Value Significance	Intercept	Co-efficient
Rainfall Tank	NIA by Tanks	Rainfall in mm	**	345149.90***	281.37***
Rainfall Wells	NIA by Wells	Rainfall in mm	*	961249.20***	437.96**
Rainfall Canals	NIA by Canals	Rainfall in mm	*	756727.60***	53.79**

*Note: ***, ** and * coefficient is significant at the 1, 2 and 5 percent level*

The results of source specific rainfall-irrigated area regression are presented in [Table-5]. Without any increase in rainfall tanks, wells and canals could irrigated around 345150 ha, 961250 ha and 756727 ha of land, respectively. Whereas, one mm increase of rainfall could increase the area irrigated by tanks, wells and canals by 281 ha, 438 ha and 54 ha, respectively. In this regression model only rainfall is used as independent variable. However it could be inferred that rainfall is one of the factor of influence for well irrigation. Rainfall has least influence on canal irrigation.

Influence of Rainfall on Groundwater

Major source of ground water recharge is the monsoon rainfall. Throughout the country about 67 percent of the annual replenishable resource is contributed by recharge from rainfall and the share of other sources viz. canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 33 percent. In Tamil Nadu, about 42 percent of the annual replenishable resource is contributed by recharge from rainfall and the share of other sources is 58 percent [22]. The outcome of rainfall on groundwater could be assessed from [Fig-4]. It could be palpable that the percentage of blocks under safe category follows the same pattern as rainfall received. Whereas the percentage of blocks under over-exploited category follows the inverse pattern of rainfall received. The percent of over-exploited blocks are alarmingly similar to that of safe blocks. A shift from critical and over-exploited blocks to safe and semi-critical blocks could be observed. Such development must be continued to augment all the blocks to safe category. Tamil Nadu is among the exceptional few states which have escaped a decline in groundwater table over the decade. And the state is also among the few states where a sporadic rise in water level of more than 4 m is also observed in isolated pockets [22]. Falling groundwater had negatively impacted sources of rural water supply and groundwater irrigators. This little development in ground water table is recent (2014-15) and the state has gone through a period of basins with falling groundwater tables. Continuing and boosting this development in ground water is the urgent and important factor for sustainability of agriculture in the state.

Conclusion

Agriculture in Tamil Nadu is highly dependent on rainfall even to the extent of recharging its major irrigation sources and ground water. Well irrigation is highly influenced by rainfall than canal and tank irrigation. From 1990s, the well irrigation and number of wells have increased in the state whereas the net irrigated area by tanks and canals have declined. The increased dependence on wells has declined the ground water table. Rainfall also influences the groundwater table. The water storage capacity has to be developed in order to recharge the groundwater thru rainfall rather to be disposed in sea. The maintenance of existing water storage structures is equally important as construction of new infrastructure. Agriculture being the major consumer of water in the state, the increase in population, declining ground water, development of manufacturing and service sector might cause a shift in water allocation in the state. It is high time to plan crop production based on the available resources so that the water resources are used sustainably. Prior to planning for sustainable crop production, the stock on available data of water resources have to be assessed and accessed to enable a prudent effort. Institutions and Departments are involved in dissemination of technologies to farmers. Ultimately, institutions must also be included in planning as such niche between the institutions and farmers has an influence towards sustainable crop production.

Application of research: An inventory analysis on stock of natural resources especially water is important to design area specific cropping pattern for the State.

Research Category: net area irrigated, rainfall, well irrigation, ground water depletion

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References:

[1] Singh N. and Om Prakash Singh (2018) *http://www.millenniumwaterstory.org/Green%20Revolution%20and%20its%20Impact%20on%20Water%20Resources.html*
[2] Economic Appraisal of Tamil Nadu (2014) Tamil Nadu - An Economic Appraisal 2011-12 to 2013-14. Department of Evaluation and Applied Research. Government of Tamil Nadu. Chennai. http://www.tn.gov.in/dear/Agriculture.pdf
[3] ENVIS Centre: Tamil Nadu State of Environment and Related Issues. (2018) *Government of Tamil Nadu. http://tnenvis.nic.in/Database/TN-ENVIS_791.aspx*
[4] Chinnadurai M., D. Suresh Kumar, S. Varadha Raj, S. Thirumalaikannan, I. Inzamam Ul Haq (2016) *Impact Evaluation of RIDF Irrigation Projects Funded by NABARD in Tamil Nadu. Final report submitted to National Bank for Agriculture and Rural Development. Mumbai*.
[5] Janakarajan S. and Marcus Moench (2006) *Economic and Political Weekly*. 41(37): 3977-3987.
[6] Feng Y. and Eduardo Segarra. (1992) *Texas J. Agric. Nat. Resour*., 5, 59-65.
[7] Ochola W.O., Kerkides P. (2003) *Irrigation and Drainage*,52, 327-342.
[8] Raheem M.A., Yahya W.B., Obisesan K.O. (2015) *Journal of Environmental Statistics*, 7(1), 1-13.
[9] Oduwole H.K., Binbol N.L., Shawulu H.M. 2011) *Nigerian Journal of Pure and Applied Science*, 4, 118-125.
[10] Bairagi A., Sarat Ch. Kakaty (2017) *Journal of Business and Management*. 19(12), 25-31.
[11] Kumar D.S. and Palanisami K. (2010) *Agricultural Economics Research Review*, 23, 265-272.
[12] Rao D., Shahid Parwez (2005) *Indian Journal of Agricultural Economics*, 60, 4.
[13] Mirkatouli J., Hosseini A., Neshat A. (2015) *City, Territory and Architecture*. 2, 4.
[14] Iacono, M., David Levinson, Ahmed El-G M., Wasfi Rania (2012) *Journal of Land Use, Mobility and Environment*, 8, 3.
[15] Parvez Md.R., Buddhika Madurapperuma, David Ripplinger (2015) *Paper presented in Agricultural and Applied Economics Association and Western Agricultural Economics Association Annual Meeting. Held on July 26-28. San Francisco. CA.*
[16] Dlamini, N.S., Rowshon M. K., Syazwan Faisal, Ujjwal Saha (2015) *Jurnal Teknologi (Sciences & Engineering)*, 76(15), 13–19.
[17] Yoo, C; Jinwook Lee; Yonghun Ro. (2016) *Advances in Meteorology, Volume 2016, Article ID 7957490, 10 pages*.
[18] Kei K., Palanisami K., Takeshi Sakurai (2007) *Agricultural Economics*, 36(3), 347-362.
[19] Palanisami K. (2006) *Journal of Development in Sustainable Agriculture,* 1(1), 34-40.
[20] Janakarajan (2002) *Discussion paper. Annual Partner's Meet. IWMI-TATA Water Policy Research program. IWMI. New Delhi*.
[21] Ndamni F. and Tsunemi W. (2015) *Conference paper presented in the 9th International Symposium on Social Management Systems SSMS 2013, At Sydney, Australia, Volume: 9*.
[22] Groundwater Year Book. (2017) *Central Ground Water Board, Ministry of Water Resources. Government of India*.