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VIRTUAL WATER EFFICIENCY IN COTTON PRODUCTION ACROSS THE INDIAN STATES

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ABSTRACT

Background: Water is a natural resource required for human existence on this planet. Even though we have access to nearly two-thirds of the water on the earth, there is still a severe lack of water. It's because of unequal distribution and overexploitation of water resources and withdrawal of water for use in personal and agricultural endeavours.

Objective: The objective of this article is to determine the virtual water use efficiency across the Indian states regarding cotton production.

Method and Tools: These studies based on secondary data in cotton production was taken from the INDIASTAT. The results show water requirement for cotton production is generated by the CROPWAT 8.0 model (FAO software) with the help of CLIMWET software (FAO software).

Finding: This result shows that Orissa, Punjab, and Haryana, are the most efficient states regarding virtual water use in cotton production, while Maharashtra, Rajasthan, Tamil Nadu, and Madhya Pradesh are inefficient.

Implication: The implication of this article is to decrease the average water requirement of cotton at the national level by shifting production from inefficient states to efficient states.

Keywords: Virtual Water, CROPWAT, Cotton Production, Water efficiency, Agriculture

INTRODUCTION

India is an agrarian country. Agriculture accounts for a significant portion of the total number of jobs held by the Indian people. According to Statista, in 2019, 42.6% of India's labour was engaged in agriculture, while the remaining workforce was evenly divided between the industrial and service sectors. In order to produce agricultural goods, one needs a number of different inputs and conditions, such as favourable weather, soil, temperature, tools and techniques, fertilisers, pesticides, and situations that are conducive to growth. Water is the single most important factor that is essential to cultivate crops and raise livestock successfully, in addition to the aforementioned inputs and circumstances. We would be unable to conceive anything, including farming, in the absence of water. The term 'virtual water' refers to the water that is used in the production of goods in both the agricultural and industrial sectors. The survival of every living creature depends on the availability of water more than anything else. It can be said that the presence of water on Earth is what makes it the only planet capable of supporting life. One of the most useful things we have on Earth is a solvent that can be used for various purposes. Without water, it would be impossible for anything to sustain life. Almost 70% of the planet is covered by it. There is a lot of water, but not all of it is fit for human consumption. It's a fact that we use water in our daily lives for things that matter to us.The supply of safe drinking water is dwindling as the population grows. Due to a rise in population, more water is required for agricultural output, resulting in an increase in water withdrawal (Boutraa, 2010).

There are several countries where cotton is grown as a commercial fiber crop. Cotton farming is thought to have begun 7,000 years ago, and the Indus Valley is where the first textiles made from cotton were woven 3000 years ago(The Story of Cotton- History of Cotton). Regarding cotton production, India is the second largest producer after China (Ashok, Uma, Prahadeeswaran, & Jeyanthi, 2012)(Shahbande, 2021). It takes between 10,000 and 20,000 litres of water to produce 1 kg of cotton, and the amount needed depends on the soil’s texture, the temperature, relative humidity, rainfall, sun hours, evapotranspiration, soil texture, sowing time according to the region, and radiation. For the period 1997–2001, the world's consumption of cotton goods required 256 Gm3 of water per year (Chapagain, Hoekstra, Savenije, & Gautam, 2005).

THEORETICAL FRAMEWORK

Virtual Water and Virtual Water Efficiency

This "virtual water" refers to the water that is utilised in the production of food and fibre in addition to the production of energy and other things that are not foods. It is the hidden form of water which is embedded in the product. That is why it is called virtual water. Tony Allan gave the concept of virtual water in the 1990s. Approximately 87 per cent of the world's freshwater consumption is attributable to agricultural production (Pimentel, et al., 1997). It is necessary to increase agricultural water output to meet the growing demand for food in regions with limited water resources (Pimentel, et al., 1997) (Boutraa, 2010). It takes between 10,000 and 20,000 litres of water to produce 1 kg of cotton, and the amount needed depends on the soil's texture, the temperature, relative humidity, rainfall, sun hours, evapotranspiration, soil texture, sowing time according to the region, and radiation. Approximately 10,000 to 22,000 litres of water are needed to produce one kilogram of cotton, according to the Water Footprint Network. Meanwhile, the world's water uses for producing 1 kg of cotton is 10000 litres (Leahy, 2015)(Water Footprint Network). The supply of safe drinking water is dwindling as the population grows. Due to a rise in population, more water is required for agricultural output, resulting in an increase in water withdrawal (Boutraa, 2010). To lower the virtual water use per unit, the cotton yield needs to go up. It cuts down on irrigation water waste while keeping crop yields high. This makes irrigation water more productive (Kang, et al., 2016). It is possible to do this by using modern technology to change the planting time, High-density planting techniques, and the weather in the country. G. arboreum cotton should be given top priority (Niranjan, Balaganesh, & Jamaludheen, 2017)(Dinar, 1993)(Hebbar, Venugopalan, Prakash, & Aggarwal, 2013) (Blaise & Kranthi, 2019).

Cotton Production in India

India has been growing cotton since at least 3000 BCE, which makes it one of the world's oldest crops (Santhanam & Sundaram, 1997)(The Story of Cotton- History of Cotton).India is one of the leading cotton-producing countries in the world. India has more than 60 million people engaged in the cotton textile and processing sectors because of their involvement in farming and the direct or indirect employment opportunities supplied by cotton textiles and processing companies (Blaise & Kranthi, 2019).India's cotton production has risen in recent years, providing it an advantage in both the domestic and international markets. U.S. production accounts for 38% of total global exports, although accounting for only 14% of global cotton production. Despite the fact that the United States exported 86% of its output, compared to India's 22%, the production costs of the United States is 5 to 6 times higher than India (Sharma & Bugalya, 2014).The implementation of *Bt* Cotton has resulted in an increase in cotton production in India (Bennett, Ismael, Kambhampati, & Morse, 2004) (Ashok, Uma, Prahadeeswaran, & Jeyanthi, 2012)(Stone, 2012)(Subramanian & Qaim, 2010).Despite this, the cotton yield in India is significantly lower than the global average yield. It is less than 500 kg lint/ha, although the average yield of cotton production in the world is 792 kg lint/ha (Blaise & Kranthi, 2019).Simply changing the planting date and implementing a high-density planting strategy in order to cultivate varieties with a rapid growth rate can bring about an increase in cotton yield(Hebbar, Venugopalan, Prakash, & Aggarwal, 2013) (Blaise & Kranthi, 2019). The government is required to take the necessary steps to boost productivity through research, mechanisation, and growth in exports as a result of greater production (Niranjan, Balaganesh, & Jamaludheen, 2017).

OBJECTIVES:

Objective of this article is to determine the virtual water use efficiency across the Indian states regarding cotton production.

Null Hypothesis H_0: There is no significant difference in the virtual water use in cotton production in Indian States**.**

Alternate Hypothesis H_a: There is a significant difference in the virtual water use in cotton production in Indian States.

RESEARCH METHODOLOGY

For this study, the time series data from the year 2000 to 2020 was taken from the INDIASTAT regarding all cotton production states, and the data regarding Virtual Water was calculated with the help of the CROPWAT 8.0 model. Total virtual water is taken from the sum of the green (effective rainfall) and blue water required (irrigated area taken into consideration only).

The water requirement for the cotton production in a hectare of the field was divided from the yield of that particular state to know the water requirement for the one kg of cotton production

To analyse the data, The SPSS V22 is used. The ANOVA is used to calculate the virtual water efficiency across the Indian states regarding cotton production.

DATA ANALYSIS

Table 1: The Mean Value of virtual water used is calculated by ANOVA for significant differences across Indian states. See the Virtual Water Data in the Appendix.

States	Average Water Use in a kg of cotton in litres	F-Value	p-Value	H_0 Decision	Significance Difference
Gujrat	16515	6.072	0.000	Rejected	Yes
Haryana	13594				
Karnataka	17612				
Maharashtra	22483				
Madhya Pradesh	20195				
Orissa	9252				
Punjab	9906				
Rajasthan	23635				
Tamil Nadu	21022				
Andhra Pradesh	15521				

Source: Calculated by Author

The ANOVA test results in the above table indicate significant differences in the average water use for producing one kilogram of cotton across the listed states. With an F-value of 6.072, the analysis reveals significant variations among the states, suggesting that the average water usage is not consistent across different regions. The p-value of 0.000 further supports this finding, confirming that these differences are statistically significant. Consequently, the null hypothesis is rejected. This underscores the importance of considering regional water use efficiency in cotton production.

Gujarat V/s Other States (Table no. 2 in appendix)
The analysis reveals that there is no significant difference in the virtual water use between Gujarat and other states. While each state uses different amounts of virtual water, these differences are not substantial.

Haryana V/s Other States (Table no. 3 in appendix)
The analysis reveals a significant difference in virtual water use between Haryana and Rajasthan. Haryana uses much less virtual water compared to Rajasthan. In contrast, the differences in virtual water use between Haryana and other states are minor and not significant.

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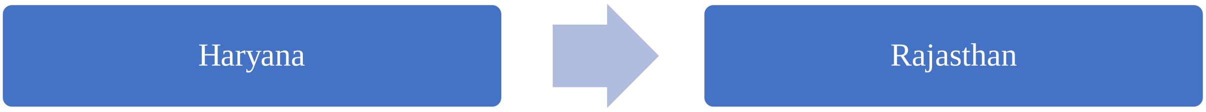


The above figure shows the virtual water use efficiency ranked in descending order. This indicates that Haryana requires less virtual water compared to Rajasthan to produce the same quantity of cotton.

Karnataka V/s Other States (Table no. 4 in appendix)
The analysis indicates that the virtual water use in Karnataka does not significantly differ from virtual water use in other states. Despite the variation in virtual water use across states, these differences are not significant.

Maharashtra V/s Other States (Table no. 5 in appendix)
The analysis indicates a significant disparity in virtual water use between Maharashtra and the states of Punjab and Odisha. Specifically, Maharashtra exhibits substantially higher virtual water use compared to these two states. In contrast, the differences in virtual water use between Maharashtra and other states are present but not statistically significant.

The above figure illustrates the virtual water use efficiency in descending order. This indicates that Maharashtra requires more virtual water than both Punjab and Odisha to cultivate the same quantity of cotton.

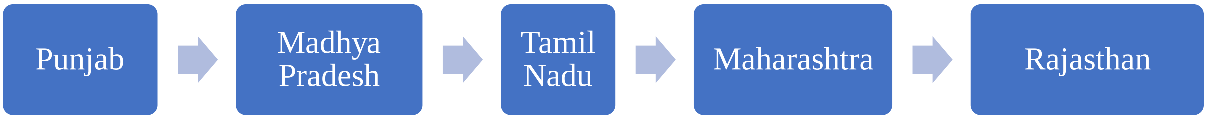
Madhya Pradesh V/s Other States (Table no. 6 in appendix)
The analysis indicates that Madhya Pradesh has a notably higher virtual water use compared to Punjab and Odisha. While differences in virtual water use exist between Madhya Pradesh and other states, these differences are not statistically significant. This highlights that, in terms of virtual water use, Madhya Pradesh has a significant difference only with Punjab and Odisha.

The above picture shows the virtual water use efficiency in decreasing order. It means Madhya Pradesh needs higher virtual water than Punjab and Odisha to grow the same amount of cotton.

Odisha V/s Other States (Table no. 7 in appendix)
The analysis reveals a significant difference in virtual water use between Odisha and the states of Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan. Specifically, Odisha uses considerably less virtual water compared to these four states. While there are differences in virtual water use between Odisha and other states, these differences are not statistically significant.

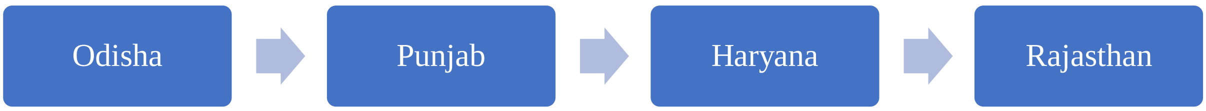
The picture above displays the virtual water use efficiency in descending order, indicating that Odisha requires less virtual water than Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan to produce the same quantity of cotton.

Punjab V/s Other States (Table no. 8 in appendix)
The analysis reveals a notable difference in virtual water usage between Punjab and several other states. Specifically, Punjab's virtual water consumption is significantly lower compared to that of Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan. When we look at other states other than these four, the differences in virtual water use become less pronounced and are not considered statistically significant. Therefore, it's clear that Punjab stands out with its more efficient use of virtual water, particularly in comparison to the high usage observed in Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan.



The image displays the virtual water use efficiency ranked in descending order, indicating that Punjab requires less virtual water compared to Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan to produce an equivalent quantity of cotton. In other words, this efficiency implies that Punjab can produce the same amount of cotton with lower virtual water inputs, potentially reflecting better agricultural practices, irrigation methods, or environmental conditions conducive to cotton farming in the region.

Rajasthan V/s Other States (Table no. 9 in appendix)
The analysis results indicate that Rajasthan's virtual water use differs significantly from that of Haryana, Punjab, and Odisha. In simple terms, Rajasthan uses significantly more virtual water compared to these three states. For the other states, while there are differences in virtual water use in cotton production, these variances are not considered significant.



The image depicts the descending order of virtual water use efficiency, indicating that Rajasthan requires more virtual water than Haryana, Punjab, and Odisha to produce an equivalent amount of cotton.

Tamil Nadu V/s Other States (Table no. 10 in appendix)
The analysis indicates a significant difference in virtual water usage between Tamil Nadu and Punjab as well as Odisha. While minor variations exist among other states, these differences are deemed insignificant. Specifically, Tamil Nadu exhibits significantly greater virtual water consumption compared to Punjab and Odisha.

The above figure projects the virtual water use efficiency rank in decreasing order. It means Tamil Nadu uses more virtual water than Punjab to grow the same amount of cotton.

Andhra Pradesh V/s Other States (Table no. 11 in appendix)
The result of the analysis shows that there is no significant difference in the virtual water use of Karnataka and the virtual water use of other states. Although each state has different virtual water use, the differences are insignificant.

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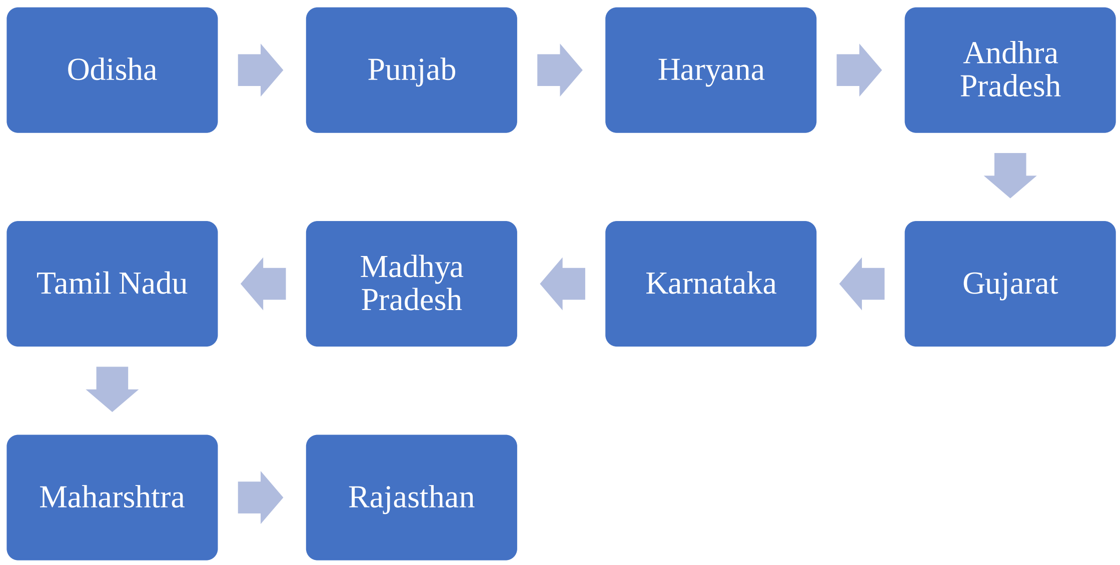
Virtual Water Efficiency State Wise in Decreasing Order



After analysing the Virtual Water Efficiency in cotton production in Indian states. It is revealed that there is difference in the virtual water efficiency of all states but there are few states in which there is no significance difference in water use efficiency with respect to other states. These states are Gujrat, Karnataka, and Andhra Pradesh (Appendix Table No. 2,4,11). Other than these states, all states which are taken in study have significance difference in virtual water efficiency with respect to other states. These states are Haryana, Maharashtra, Madhya Pradesh, Orrisa, Punjab, Rajasthan, and Tamil Nadu (Appendix Table No. 3,5,6,7,8,9,10).

CONCLUSION:

The study shows the virtual water efficiency regarding cotton production across the Indian states with the help of secondary data on cotton production and the virtual water data taken from the CROPWAT 8.0 Model by using the ANOVA tool with the help of SPSS. The result shows that Odisha, Punjab, and Haryana are the most efficient in virtual water use for cotton production while Madhya Pradesh, Tamil Nadu, Maharashtra, and Rajasthan are the least efficient states and Gujarat, Karnataka, and Tamil Nadu are at the average level. However, in some states, the Water requirement per hectare is less but the lower cotton yield in those states makes them high water use for a kg of cotton or less water efficient. It happens because water requirement depends on the area of production and not the yield of cotton. The cotton production in Maharashtra is majorly dependent on green water only. There is 2.7% of the cotton cultivation area comes under irrigation, while Andhra Pradesh has about 17% of cotton cultivation under irrigation. Still, Rajasthan is inefficient in water use in cotton production. About 1/3rd of the cotton cultivation area is dependent on irrigation in Tamil Nadu, and 2/3rd of the cotton cultivation area is dependent on irrigation in Madhya Pradesh. Haryana, Punjab, and Rajasthan have the highest cotton cultivation area under irrigation.

POLICY IMPLICATIONS

The supply of safe drinking water is diminishing as the population increases. This population growth demands more water for agricultural production, leading to higher water withdrawals To reduce this water consumption, the government should implement measures for sustainable production, achieving more output with less water usage. Based on this study's findings, the government should act to enhance productivity by adopting new drought-resistant seeds for rainfed areas. This approach will boost productivity and reduce water consumption per unit of production. Additionally, the government should focus on improving productivity in Rajasthan, as cotton production there is the least water-efficient, despite having the largest irrigated area, exacerbating its water use inefficiency.

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Appendix:

Table No. 2: Comparison: Gujarat V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Gujrat	Haryana	2920	0.991	Accepted	No
	Karnataka	-1098	1.000	Accepted	No
	Maharashtra	-5968	0.545	Accepted	No
	Madhya Pradesh	-3680	0.957	Accepted	No
	Orissa	7263	0.259	Accepted	No
	Punjab	6609	0.392	Accepted	No
	Rajasthan	-7120	0.286	Accepted	No
	Tamil Nadu	-4508	0.861	Accepted	No
	Andhra Pradesh	993	1.000	Accepted	No

Sources; Author's Calculation

Table No. 3: Comparison: Haryana V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Haryana	Gujrat	-2920	.991	Accepted	No
	Karnataka	-4018	.926	Accepted	No
	Maharashtra	-8888	.067	Accepted	No
	Madhya Pradesh	-6601	.394	Accepted	No
	Orissa	4343	.886	Accepted	No
	Punjab	3688	.956	Accepted	No
	Rajasthan	**-10041***	**.020**	**Rejected**	**Yes**
	Tamil Nadu	-7428	.231	Accepted	No
	Andhra Pradesh	-1927	1.000	Accepted	No

Sources; Author's Calculation

Table No. 4: Comparison: Karnataka V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Karnataka	Gujrat	1098	1.000	Accepted	No
	Haryana	4018	.926	Accepted	No
	Maharashtra	-4870	.796	Accepted	No
	Madhya Pradesh	-2582	.996	Accepted	No
	Orissa	8361	.109	Accepted	No
	Punjab	7707	.187	Accepted	No
	Rajasthan	-6023	.531	Accepted	No
	Tamil Nadu	-3410	.974	Accepted	No
	Andhra Pradesh	2091	.999	Accepted	No

Sources; Author's Calculation

Table No. 5: Comparison: Maharashtra V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Maharashtra	Gujrat	5968	.545	Accepted	No
	Haryana	8888	.067	Accepted	No
	Karnataka	4870	.796	Accepted	No
	Madhya Pradesh	2288	.999	Accepted	No
	Orissa	**13231***	**.000**	**Rejected**	**Yes**
	Punjab	**12577***	**.001**	**Rejected**	**Yes**
	Rajasthan	-1152	1.000	Accepted	No
	Tamil Nadu	1460	1.000	Accepted	No
	Andhra Pradesh	6961	.317	Accepted	No

Sources; Author’s Calculation

Table No. 6: Comparison: Madhya Pradesh V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Madhya Pradesh	Gujrat	3680	.957	Accepted	No
	Haryana	6601	.394	Accepted	No
	Karnataka	2582	.996	Accepted	No
	Maharashtra	-2288	.999	Accepted	No
	Orissa	**10943***	**.007**	**Rejected**	**Yes**
	Punjab	**10289***	**.015**	**Rejected**	**Yes**
	Rajasthan	-3440	.972	Accepted	No
	Tamil Nadu	-827	1.000	Accepted	No
	Andhra Pradesh	4673	.833	Accepted	No

Table No. 7: Comparison: Odisha V/s Other States

State (I)	States (J)	Mean Difference (I-J)	p-value	H_0 Decision	Significance Difference
Orissa	Gujrat	-7263	.259	Accepted	No
	Haryana	-4343	.886	Accepted	No
	Karnataka	-8361	.109	Accepted	No
	Maharashtra	**-13231***	**.000**	**Rejected**	**Yes**
	Madhya Pradesh	**-10943***	**.007**	**Rejected**	**Yes**
	Punjab	-654	1.000	Accepted	No

	Rajasthan	**-14383***	**.000**	**Rejected**	**Yes**
	Tamil Nadu	**-11770***	**.002**	**Rejected**	**Yes**
	Andhra Pradesh	-6270	.471	Accepted	No

Table No. 8: Comparison: Punjab V/s Other States

State (I)	**States (J)**	**Mean Difference (I-J)**	**p-value**	**H_0 Decision**	**Significance Difference**
Punjab	Gujrat	-6609	.392	Accepted	No
	Haryana	-3688	.956	Accepted	No
	Karnataka	-7707	.187	Accepted	No
	Maharashtra	**-12577***	**.001**	**Rejected**	**Yes**
	Madhya Pradesh	**-10289***	**.015**	**Rejected**	**Yes**
	Orissa	654	1.000	Accepted	No
	Rajasthan	**-13729***	**.000**	**Rejected**	**Yes**
	Tamil Nadu	**-11116***	**.006**	**Rejected**	**Yes**
	Andhra Pradesh	-5616	.631	Accepted	No

Sources; Author's Calculation

Table No. 9: Comparison: Rajasthan V/s Other States

State (I)	**States (J)**	**Mean Difference (I-J)**	**p-value**	**H_0 Decision**	**Significance Difference**
Rajasthan	Gujrat	7120	.286	Accepted	No
	Haryana	**10041***	**.020**	**Rejected**	**Yes**
	Karnataka	6023	.531	Accepted	No
	Maharashtra	1152	1.000	Accepted	No
	Madhya Pradesh	3440	.972	Accepted	No
	Orissa	**14383***	**.000**	**Rejected**	**Yes**
	Punjab	**13729***	**.000**	**Rejected**	**Yes**
	Tamil Nadu	2613	.996	Accepted	No
	Andhra Pradesh	8114	.135	Accepted	No

Sources; Author's Calculation

Table No. 10: Comparison: Tamil Nadu V/s Other States

State (I)	**States (J)**	**Mean Difference (I-J)**	**p-value**	**Decision**	**Significance Difference**
Tamil Nadu	Gujrat	4508	.861	Accepted	No

	Haryana	7428	.231	Accepted	No
	Karnataka	3410	.974	Accepted	No
	Maharashtra	-1460	1.000	Accepted	No
	Madhya Pradesh	827	1.000	Accepted	No
	Orissa	**11770***	**.002**	**Rejected**	**Yes**
	Punjab	**11116***	**.006**	**Rejected**	**Yes**
	Rajasthan	-2613	.996	Accepted	No
	Andhra Pradesh	5501	.658	Accepted	No

Table No. 11: Comparison: Andhra Pradesh V/s Other States (AP & Telangana Merged)

State (I)	**States (J)**	**Mean Difference (I-J)**	**p-value**	**Decision**	**Significance Difference**
Andhra Pradesh	Gujrat	-993	1.000	Accepted	No
	Haryana	1927	1.000	Accepted	No
	Karnataka	-2091	.999	Accepted	No
	Maharashtra	-6961	.317	Accepted	No
	Madhya Pradesh	-4673	.833	Accepted	No
	Orissa	6270	.471	Accepted	No
	Punjab	5616	.631	Accepted	No
	Rajasthan	-8114	.135	Accepted	No
	Tamil Nadu	-5501	.658	Accepted	No