Water Productivity In India: Inter-State Analysis, 1980-83 And 2008-11

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Abstract

Indian agriculture is gamble of monsoon. As we know that Indian monsoon plays significant role to determine the agricultural production of the country which directly affects national economy and the growth of the other sectors as well. If we see the present scenario, year 2012 can be viewed as a monsoon deficient year. With each passing day, the threat of an unprecedented drought seems closer to reality. Desperate farmers have sown paddy two to three times, only to see the crop wither. The trouble, the report showed, was brewing especially for the wheat crop with production showing a perceptible decline since 2000. The gross capital formation in agriculture, as a proportion to the GDP, has shown a decline from 2002-02 to 2007-08, the economic survey said. The overall food grain produce as a consequence fell short of the target for 2007-08 as well as 2008-09. Approximately, 70 percent of total administrative sub-divisions in the country, rains have been scanty or we can say deficient. So this monsoon is turning out to be India’s season of despair. Therefore, there is an urgent need to increase water productivity, more particularly in water scares regions. This is primarily due to inadequate water resources to meet increasing water demand in different sectors. Among alternative options, improving productivity of water use has significant potential. Thus, like the campaign for more crops per unit of land during the period of the green revolution, improving water productivity is also gaining prominence now.

Keywords: Agriculture, Agro Climatic Regions (ACR), India, Land Productivity, Water Consumption Index (WCI), Water Productivity.

Introduction

Water is a precious and finite resource. Although it covers three quarters of the earth, only a small fraction is accessible as fresh water. Of the total amount of water withdrawn, almost 70 percent is needed to produce the food that fuels human activity. It is the most critical input for agricultural productivity. Population is increasing and consumption patterns are also diversifying towards high value crops with high water requirements (Kumar et al.2003; Joshi et al.2004), so production will have to increase significantly to meet additional food and food grain demand. But with increasing water demand for high-value crops, and from other sectors, food grain production will face stiff competition for scarce water resource. Improving water productivity is one option for coping with water scarcity (Amarasinghe et al., 2007). Though land is another natural resource along with water, but water can improve or destroy its productivity with proper or improper management. Water can cause salinity, silting, degradation, gullies, ravines, etc. on the soil. The soil is dependent on water, which is an independent resource. Soil management and improvement depends upon water. Serious imbalances like excess rainfall in northeast and deficient rainfall in most other parts have led to problems like floods in excess rainfall areas and drought in deficient rainfall areas with reversal trends. So proper water quantity (proper rainfall) and distribution (distribution of rainfall) is a key factor and is an issue to raise the water productivity in India, however more water use resulting in higher production may not always be true (ibid). So there should be an optimum balance between water quantity and rainfall distribution. A shift in the paradigm from land productivity to water productivity is being witnessed at the dawn of the new century the world over. Conservation and efficient use of every drop of water for enhancing food crop production is Water productivity (kg./ hectare mm).

The concept of water productivity is based on “more crop per drop” or “producing more food from the same water resources” or “producing the same amount of food from less water resources”. In
a broad sense, productivity of water is related to the value or benefit derived from the use of water. Therefore, taking the rising aforesaid issues into consideration, the present study would make a detailed analysis of changes in aggregate land and water productivity in different agro climatic regions in India during 1980-2011 by following objectives and research questions. In nutshell, the present paper, an attempt has been made to analyze the interrelationship between water productivity of different crops and their land productivity.

**Objectives**

- To study the trends and patterns of aggregate water productivity along with aggregate land productivity of different crops across the different regions in India.
- To examine the interrelationship between aggregate land and water productivity of irrigated and less irrigated regions in India.

**Research Questions**

1. Is there a convergence between the variations of aggregate land productivity and water productivity?
2. Does the aggregate water productivity in a region decline with increase in irrigation extent?
3. Is the aggregate water productivity of crops higher in dominantly tube well irrigated area compared to other irrigated areas?

**Data Sources**

i. Agriculture statistics of India, Ministry of Agriculture, Government of India for the study period.
iii. The Statistical Abstract of India and, Agricultural statistics of the Directorate of Economics and Statistics, Ministry of Agriculture have been used for the study period.
vi. For, Whole Sale Price Index – Annual Average, Base 1993-94 of All Commodities has taken by Office of the Economic Adviser, Ministry of Commerce and Industry, Government of India.

**Methodology**

In order to classify different agro climatic regions the criteria and concepts of Agro-climatic Regional Planning Project (ARCP) of the Planning Commission has been used. The project was initiated by regionalizing the country in to 15 agro-climatic regions and later in to 73 sub regions, having a higher degree of commonality. The principles used for this sub-regionalization related intrinsically with the character of the agricultural economy, namely, soil type, climate, temperature and its variations, rainfall and other-meteorological characteristics, water demand and supply characteristics including quality of water and aquifer conditions1. Humid region is further divided into moderate and low irrigated regions while semi-arid region has three sub divisions viz. highly irrigated, moderately irrigated and less irrigated regions on the basis of their levels of irrigation extent.

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Weighted Water Requirements

The data of different crop water requirement (in mm) is based on the regional level, to make this available data useful at the state level. The aggregate water requirement has been worked out by weighting the water demand of each agro-climatic type with the areal extent of the region in the state. E.g. - suppose there are three regions in the state A (arid), SH (Semi-arid) and H (humid). Now if the areal extents of these agro climatic types are 60%, 30% and 10% respectively, the weights of these regions in the state become 0.6, 0.3 and 0.1 respectively. Suppose the water demand of rice for state ‘A’ is 1200(mm), 900(mm) and 600 (mm) respectively for arid, semi-arid and humid conditions, the weighted water demand of the state can be calculated as (1200*0.6) + (900*0.3) + (600*0.1). The weighted water requirement for the given example of rice for state ‘A’ would be 1050 mm. It should be noted here that the water requirement data is given in units of depth.

Likewise, we can derive the weighted water requirement of various crops for the states in different agro climatic regions. Hence, weighted water requirement of different crops across the states has been used for the study. This estimation would have problems as it would be assuming that rice is grown in the state uniformly in all regions i.e. ratio of area under rice in all the regions to their respective GCA is similar. The data for water requirement of crops has been taken from sources of Indian Agricultural Research Institute.

Total Water Consumption Index

To identify the total water consumption of crops in a particular state, the values of total water consumption has been calculated: It is computed by the multiplication of weighted water requirements of \( i^{th} \) crop with the areal extent of \( i^{th} \) crop divided by GCA of selected \( i^{th} \) crops.

\[
TWCI = \frac{\sum \text{(Weighted Water requirement of } i^{th} \text{ crop}) \times \text{(area of } i^{th} \text{ crop)}}{\text{GCA of } i^{th} \text{ crop}}
\]

Where, \( i = 1, 2, 3 \ldots N \) (No. of crops). Value of total water consumption index would give the level of total water consumption of the particular states with respect to areal extent of different crops which have different water requirements. It will be accounted water consumption as mm in particular state.

Aggregate Land Productivity

It is the aggregate sum of total productivity of \( i^{th} \) crop with respective to the GCA of the state. For monetary value of aggregate land productivity, value of output (in Rs.lac.) has been used by making it constant so we have inflated and deflated the current price of value of output with the wholesale price index, for all commodities with linking factors have been used. Its unit is Rs.lakh/hectare.

Aggregate Water Productivity

It is the aggregate sum of total productivity of \( i^{th} \) crop with respective to water requirements and areal extent of \( i^{th} \) crops of the state. For monetary value of aggregate water productivity, again value of output (in Rs.laksh.) has been used. It can be derived by:

\[
\text{Aggregate Water Productivity} = \frac{\sum \text{(Production of } i^{th} \text{ crop} \times \text{Price of } i^{th} \text{ crop}) \times \text{(area of } i^{th} \text{)}}{\sum \text{(Water req. of } i^{th} \text{ crop}) \times \text{(area of } i^{th} \text{)}}
\]

Hukkeri, S.B and Pandey S.L, Water requirement and irrigation of crops, I.A.R.I, Pusa, New Delhi

Value of output include the production and price of \( i^{th} \) crops
Where, \( i = 1, 2, 3 \ldots N \) (No. of crops), its unit is Rs lakh./hectare millimetres. Areas of \( i^{\text{th}} \) crop as numerator have been used for giving the weightage to all crops.

Total Water Consumption Index

Map-1

Map-2

Map-3
Maps 1 and 2 show that all the western states which have been diversified have low level of water consumption of crops in reverse of that states which have been highly irrigated by tube well irrigation, they have high water consumption level. States like Punjab, Haryana, Uttar Pradesh, Andhra Pradesh and Tamil Nadu have high irrigation extent and their major crop combinations are also from highly water intensive crops. All the highly irrigated semi-arid states tend to move towards higher water intensive crops whereas there is no major changes can be seen for all the humid states. Total water consumption index has increased remarkably in Gujarat. Gujarat is state where ground water dependence is highest.

Spatial Distribution of Land and Water Productivity

a. Aggregate Land Productivity

<table>
<thead>
<tr>
<th></th>
<th>LP_80-83</th>
<th>LP_90-93</th>
<th>LP_00-03</th>
<th>LP_08-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately Irrigated States</td>
<td>113.95</td>
<td>169.13</td>
<td>190.66</td>
<td>217.91</td>
</tr>
<tr>
<td>Less Irrigated States</td>
<td>328.79</td>
<td>569.56</td>
<td>602.77</td>
<td>790.82</td>
</tr>
<tr>
<td>Semi-Arid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly Irrigated States</td>
<td>247.26</td>
<td>354.10</td>
<td>421.62</td>
<td>548.08</td>
</tr>
<tr>
<td>Moderately Irrigated States</td>
<td>246.04</td>
<td>312.82</td>
<td>333.83</td>
<td>427.45</td>
</tr>
<tr>
<td>Less Irrigated States</td>
<td>205.03</td>
<td>326.51</td>
<td>349.19</td>
<td>525.60</td>
</tr>
<tr>
<td>Arid</td>
<td>30.69</td>
<td>49.89</td>
<td>51.65</td>
<td>68.43</td>
</tr>
<tr>
<td>Source: Computed from data sources of the study</td>
<td></td>
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</tr>
</tbody>
</table>

b. Aggregate Water Productivity

<table>
<thead>
<tr>
<th></th>
<th>LP_80-83</th>
<th>LP_90-93</th>
<th>LP_00-03</th>
<th>LP_08-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately Irrigated States</td>
<td>174.81</td>
<td>260.48</td>
<td>294.19</td>
<td>341.60</td>
</tr>
<tr>
<td>Less Irrigated States</td>
<td>465.15</td>
<td>800.49</td>
<td>833.07</td>
<td>1093.14</td>
</tr>
<tr>
<td>Semi-Arid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly Irrigated States</td>
<td>319.78</td>
<td>420.17</td>
<td>465.47</td>
<td>602.83</td>
</tr>
<tr>
<td>Moderately Irrigated States</td>
<td>355.43</td>
<td>446.09</td>
<td>436.05</td>
<td>547.85</td>
</tr>
<tr>
<td>Less Irrigated States</td>
<td>385.32</td>
<td>624.79</td>
<td>622.72</td>
<td>911.06</td>
</tr>
<tr>
<td>Arid</td>
<td>71.07</td>
<td>117.57</td>
<td>120.24</td>
<td>161.27</td>
</tr>
<tr>
<td>Source: Computed from data sources of the study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of the above tables (1 and 2), results following conclusions:

1. Water productivity of different crops is relatively higher where the land productivity has been increased over the time.

2. Though Aggregate water is increasing with the land productivity but in case of semi-arid high and moderately irrigated states, the gap between the land and water productivity is much sharper and increasing as compared to less irrigated states which is the questionable concept of sustainability of these regions.
Comparison between Land and Water Productivity

This section compares the land and water productivity in different agro-climatic regions between 1980-83 and 2008-11. For this purpose the 17 major states of India are divided into 3 broad agro-climatic regions namely, a) humid region, b) semi-arid region and c) arid region which comprise 5, 11 and 1 states respectively. Humid region is further divided into moderate and low irrigated regions while semi-arid region has three sub divisions viz. highly irrigated, moderately irrigated and less irrigated regions. Both the indices have divided by 1 to make a comparable.

Figure 1, Comparisons of Aggregate Land and Water Productivity Indices

Figure 1 shows the aggregate land and water productivity from 1980-83 to 2008-11 for moderately irrigated humid states viz. West Bengal and Bihar. Here it is clearly visible that both have shown a similar trend. During the considered period both land and water productivity have increased sharply between 1980-83 and 1990-93 then they showed a moderate increase followed by a decline in both. In West Bengal, the land and water productivity have been almost same whereas in case of Bihar, the water productivity were same in the 1980-83, since then the gap between water and land productivity has been increasing with water productivity being higher than the land productivity. This trend shows a positive indication for the sustainability of both the resources in this state.

Figure 2, Comparison of Aggregate Land and Water Productivity Indices

Figure 2 shows the comparison of land and water productivity in humid and less irrigated states.
Lesser irrigated humid region comprises Assam, Kerala and Orissa. It can be observed that land and water productivity are highly correlated in all three states showing different trends. Kerala is the leading state showing higher land and water productivity with increasing trend, while Assam has shown a marginal increase from 1980-83 to 2000-03 followed by a decline. On the other hand Orissa does not show any trend.

Figure3, Comparison of Aggregate Land and Water Productivity indices

The semi-arid highly irrigated region (Punjab, Haryana and Uttar Pradesh) has shown presents a completely different picture it shows that land and water productivity in these states were same in 1980-83, which have moderately increased till 2000-03 then showed a marginal decline. An important observation is that the gap between land and water productivity is increasing with land productivity being higher than the water productivity. These are the states which have been extracting their ground water resources for a long period of time which led to an increase in the land productivity at the cost of higher water consumption.

Figure4, Comparison of Aggregate Land and Water Productivity Indices
In the case of moderately irrigated semi-arid region, two states namely Tamil Nadu and Andhra Pradesh have shown a trend similar to the highly irrigated region. A declining trend is observed in both land and water productivity for Jammu and Kashmir.

**Semi-Arid and Less Irrigated Region**

In case of less irrigated semi-arid region it is observed that four (Madhya Pradesh, Himachal Pradesh, Maharashtra and Karnataka) out of five states have a similar trend where land and water productivity both are relatively higher than other regions. Land productivity has shown marginal increase during the considered period. Only state is Gujarat has shown a sharp increase in both land and water productivity between 1980-83 and 2000-03 than again showed an increase. Equally important to note is that the increase in water productivity is much sharper than the land productivity. This region has shown an efficient utilization of both the resources which can be attributed to their distinct cropping pattern which is less water intensive.

**Arid Region**

Rajasthan is the only arid state which shows a similar trend as shown by semi-arid less irrigated states. It has almost same water and land productivity and both have been increasing during the considered period.
Table 3
Correlations between Aggregate Water Productivity and Irrigation Extent

<table>
<thead>
<tr>
<th>Aggregate Water Productivity</th>
<th>Correlations (1981-2011)</th>
<th>Irrigation Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>Pearson Correlation</td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.959</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>1991</td>
<td>Pearson Correlation</td>
<td>-0.171</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.512</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>2001</td>
<td>Pearson Correlation</td>
<td>-0.116</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.657</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>2011</td>
<td>Pearson Correlation</td>
<td>-0.127</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.626</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>17</td>
</tr>
</tbody>
</table>

Source: Computed from data sources of the study

Data has shown that there is a negative but not significant interrelationship between aggregate water productivity and irrigation extent because 'r' value between these two variables is insignificant that correlation is general but shows negative trend that means irrigation extent is increasing the aggregate water productivity is decreasing. The entire semi-arid highly irrigated states and humid states as well experienced the same trend. Thus it can be stated that aggregate water productivity declining with increase in irrigation extent. In case of Irrigation Intensity in 1980-83, though there was positive but not significant interrelationship between aggregate land and water productivity but afterwards it has been found negative but not significant interrelationship because 'r' value between these two variables became negative with and becoming more negative till 2011. It shows that as irrigation intensity is increasing the aggregate water productivity is declining.

Aggregate Water Productivity and Tube Well Irrigation

Data reveals that till 2001, there was a positive but not a strong relationship between the aggregate water productivity and tube well irrigation, but in 2011 it has become negative. In recent period of time, mostly all the states having larger proportion of tube well irrigation, ground water has been exploited in most of the semi-arid highly irrigated states, though land productivity is increasing but aggregate water productivity is not increasing because water productivity has increased up to certain level after that the excessive use of water can lead a serious consequences like alkalization and land salinization. There is strong positive relationship between tube well irrigation and aggregate water productivity for semi-arid highly irrigated states but it is not strong as for less irrigated semi-arid states and it reverse of that there is negative relationship for humid states for all the time. That indicates over the time period factors other than tube well irrigation seems to have changing the importance in terms of their contribution to crop productivity.

Interrelationship between Land and Water Productivity

a. Interrelationship between Aggregate Land and Water Productivity

There is positive high significant interrelationship between the different land and water productivity of selected crops and correlation results have shown that there is a significantly high positive interrelationship at 0.01 significant levels between high aggregate land productivity and aggregate water productivity. However, it does vary between highly irrigated and less irrigated states across different agro climatic regions in India.
b. Interrelationship between Lands, Water Productivity and Water intensive crops.

There is significant positive interrelationship between Land and water productivity of water intensive crops at 99 percent of significance level (2-tailed) for all the time. Coefficient ‘r’ value is satisfactory. By the time period interrelationship between land and water productivity of wheat is increasing but in reverse of that ‘r’ value is marginally decrease in the case of rice and sugarcane, though still land and water productivity have significantly correlated for these crops.

Conclusion

The correlation of land and water productivity is significant for all periods of time, though the strength of the association is more for the aggregate land and water productivity than the individual crops. Over a period of time, the comparison of indices of land and water productivity reveals an interesting trend. The water productivity in less irrigated semi-arid regions and the dominantly humid states have increased faster or at the same rate as land productivity. On the other hand, in case of the highly or moderately irrigated semi-arid states, the aggregate land productivity has increased faster than the water productivity. The above has happened because of movement towards a highly water intensive cropping pattern in the semi-arid irrigated states and a movement away from rice albeit to a lesser extent in the humid states.

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References


