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Dynamics of Rice Production in India-Emerging sustainability issues - Options Available

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Abstract

Rice is an important cereal food crop in India and is cultivated in diverse agro-ecological regions in India. An attempt is made in this paper to trace the dynamics of rice cultivation in the last two decades in India at state level by using data at two points of time, and identify emerging sustainability related issues and available options for handling the issues. It is observed that dynamics of paddy production in some states is not explained exclusively by economics of paddy cultivation. Further there is growing concern regarding mismatch between hydrological suitability and paddy area expansion in some areas. Several policy and technological options are being suggested to correct this mismatch and also address sustainability issues associated with rice cultivation. But many of these options are focussing on any one single sustainability issue only. Hence, for addressing several sustainability issues simultaneously, basing on SRP framework, India has to develop its own standards. Policies, technological options and future research on rice need to be aligned towards the so developed standards. Along with this there is need for delineating areas suitable for rice cultivations, based on hydrological suitability..

Key words: Sustainability, dynamics, water productivity, rice, paddy.

Introduction

Rice is an important cereal food crop in India, constituted 22 percent of Gross Sown Area (GSA) of the country in 2014-15. In 2015-16, value of output of rice crop constituted 14 percent of total value of output from crops in India. In 2016-17 rice was cultivated in 43.19 million hectares in India, resulting in rice production of 110.15 million tonnes. As per recent estimates, rice production in India stands at 111.01 and 115.60 million tonnes in 2017-18 and 2018-19 respectively. A plethora of policies *viz*., Minimum Support Price (MSP) policy, paddy procurement policy, Buffer stock maintenance policy, Public distribution policy, and National food security Act (2013), rice export-import policy, input subsidy policy and policy on rice research are influencing incentives to different stakeholders in rice sector in India, thereby leading to observed outcomes of area, production and productivity. India is the largest exporter of rice in triennium ending 2016-17, with a share of 25.6 percent (CACP, 2018). Rice is cultivated in diverse agro-ecological regions in India. In this backdrop an attempt is made in this paper to trace the dynamics of rice cultivation in the last two decades in India at state level, and identify emerging sustainability related issues (based on review) and available options for handling the issues.

Methodology

The study is based on secondary data collected from various Government Publications available in public domain. Data on rice area, production, yield, MSP, procurement of paddy were collected from Agricultural Statistics at Glance-2017 published by Directorate of Economics and Statistics (DES), Government of India (GOI-2017), New Delhi, and Hand book of statistics on Indian States 2017-18 published by Reserve Bank of India. Data on cost of cultivation of paddy was collected from publications of Directorate of Economics and Statistics, GOI, New Delhi. Standard cost concepts were used in analysis which are as given below.

Cost A1 = Value of hired human labour + value of hired bullock labour + value of owned bullock labour + value of owned machinery labour + hired machinery charges + value of seed (both farm produced and purchased) + value of insecticides and pesticides + value of manure both owned and purchased + value of fertilizer + depreciation on implements and farm building + irrigation charges + land revenue, cesses and other taxes + interest on working capital + miscellaneous expenses

Cost A2 = Cost A1 + Rent paid for leased in land

Cost B1= Cost A1 + interest on value of owned fixed capital assets (excluding land)

Cost B2 = Cost B1 + rental value of owned land (net of land revenue) and rent paid for leased in land

Cost C2 = Cost B2 + imputed value of family labour

Cost A2+FL= Cost A2+ imputed value of family labour

Tabular analysis was used in analysing the data. Major portion of the analysis in the current study is based on data pertaining to two selected years of recent two decades i.e., 1996-97 (starting year) and 2016-17 (ending year). In 2016-17, more number of states were there compared to 1996-97, as some new states were carved out from other states. Hence for comparison in analysis, wherever necessary, data of new states were combined with data of their respective parent states.

Results and discussion

Area under rice in India has increased from 41.24 million ha in 1983-84 to 43.19 million ha in 2016-17, indicating an increase of 1.95 million ha (Fig.1). During the same period rice production has increased from 60.10 million tonnes to 110.15 million tonnes. Maximum area under rice (45.54 million ha) was reported in 2008-09. Between the years 1983-84 and 2016-17, rice yield per hectare increased from 14.57 quintals to 25.50 quintals, still lower than global average yield. However within India, wide regional variation is observed in rice yield. In 2016-17 maximum rice yield of 39.96 quintal was observed in the case of Punjab and lowest rice yield of 18.47 quintals was observed in the case of Madhya Pradesh.

Table 1: State wise rice area, production and yield in selected years

States/Union Territories	Rice area (million ha)		Rice production (million tonnes)		Rice yield (Kg/ha)		Area under irrigation (%)
	1996-97	2016-17	1996-97	2016-17	1996-97	2016-17	2014-15
Andhra Pradesh	4.11	2.11	10.69	7.45	2601	3531	97.1
Assam	2.49	2.45	3.33	5.23	1336	2135	11.0
Bihar	5.07	3.29	7.28	7.48	1437	2274	65.0
Chhattisgarh	na	3.83	na	8.05	na	2102	35.7
Gujarat	na	0.84	0.95	1.93	na	2298	61.5
Haryana	0.83	1.39	2.46	4.45	2964	3201	99.9
Jharkhand	na	1.59	na	3.56	na	2239	5.0
Karnataka	1.36	1.01	3.21	2.54	2364	2515	76.0
Madhya Pradesh	5.40	2.29	5.94	4.23	1101	1847	34.2
Maharashtra	1.48	1.63	2.61	3.35	1769	2055	26.1
Odisha	4.47	3.88	4.44	8.38	993	2160	33.3
Punjab	2.16	2.76	7.33	11.03	3397	3996	99.7
Tamil Nadu	2.17	1.44	5.81	4.04	2671	2806	94.4
Telangana	na	1.68	na	5.17	na	3077	98.1
Uttar Pradesh	5.55	5.65	11.77	12.95	2121	2292	86.7
Uttarakhand	na	0.26	na	0.63	na	2423	70.0
West Bengal	5.80	5.15	12.64	15.09	2179	2930	46.9
All India	**43.43**	**43.19**	**81.74**	**110.15**	**1882**	**2550**	**60.1**
Andhra Pradesh (Undivided)	4.11	3.79	10.69	12.62	2601	3330	
Bihar (Undivided)	5.07	4.88	7.28	11.04	1437	2262	
Madhya Pradesh (Undivided)	5.40	6.12	5.94	12.28	1101	2007	
Uttar Pradesh (Undivided)	5.55	5.91	11.77	13.58	2121	2298	

Source: Agricultural Statistics at a glance, different years

na: Not available

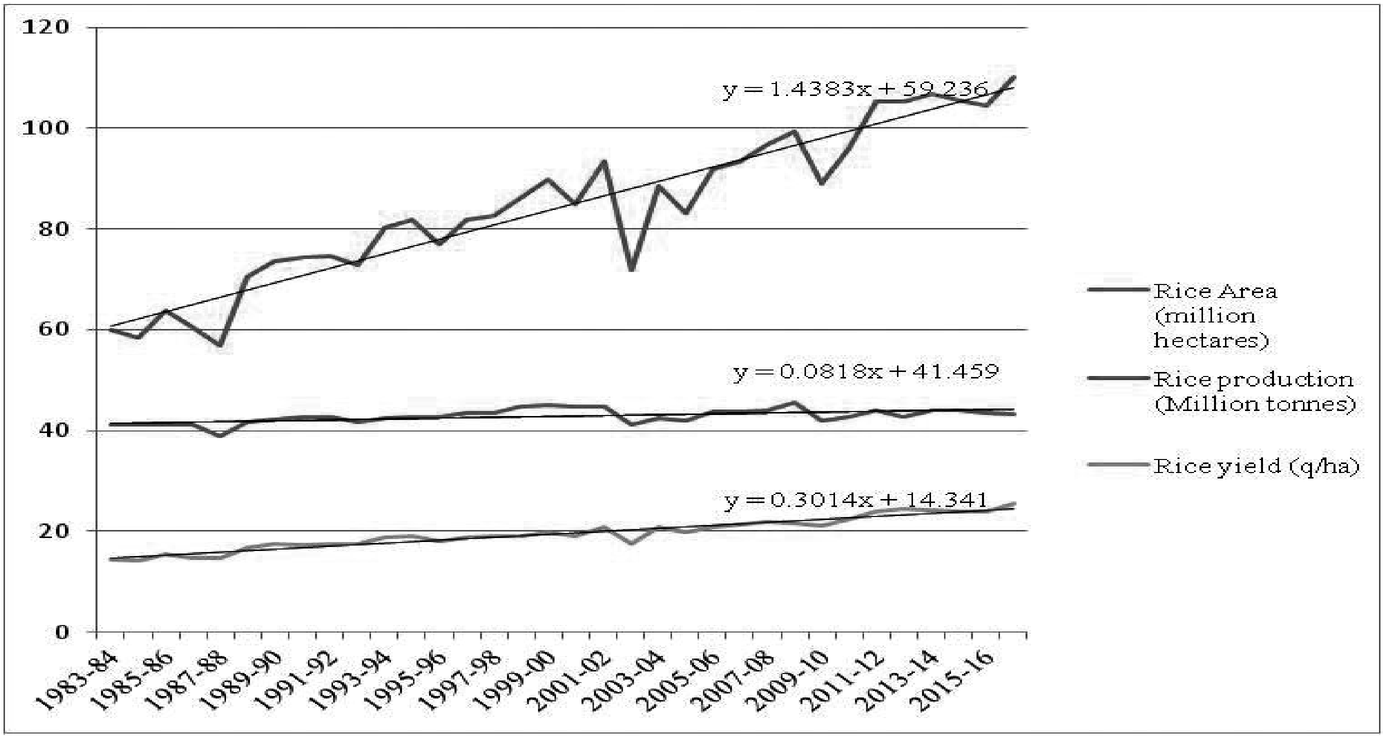

Figure 1: All India rice area, production and yield trends

Results of State level analysis of data on rice area, production and yield are presented in Table.1. In 2016-17 all India rice area decreased by 0.24 million ha compared to rice area in 1996-97. The decrease in rice area was due to decrease in rice area in Andhra Pradesh (undivided), Assam, Bihar (undivided), Karnataka, Odisha, Tamil Nadu and West Bengal. These states together contributed 58.64 percent rice area and 57.98 percent of rice production in the country in 1996-97. But in 2016-17, their contribution decreased to 52.33 and 53.51percent in all India rice area and production respectively. Out of these states, Andhra Pradesh (undivided), Karnataka, Tamil Nadu and West Bengal were the states with average rice yields higher than national average yields both in 1996-97 and 2016-17. Further in case of Karnataka and Tamil Nadu, decline in rice area was associated with decrease in total rice production in 2016-17 compared to 1996-97.

In 2016-17 rice area increased compared to 1996-97 in Haryana, Madhya Pradesh (undivided), Maharashtra, Punjab, and Uttar Pradesh (undivided). These states together contributed 35.49 and 36.85 percent of country's rice area and production respectively in 1996-97. Their share in India's rice area and production increased to 41.24 and 40.57 percent respectively in 2016-17. Out of these states, Punjab and Haryana are high yielding states.

Is this rice dynamics is associated with change in profitability of rice crops in these states?

This issue is analysed, utilizing state wise cost of cultivation data for paddy for the years 1996-97 and 2015-16 (latest year for which data is available) in the present study. Himanshu (2018) reported that in case of rice, at all India level, MSP margin over C2 cost varied between 1 percent to 47 percent in the period 2004-05 to 2017-18. In the current study it is observed that C2 cost per Quintal of output was more than Minimum Support Price (MSP) in the case of Andhra Pradesh (undivided), Assam, Haryana and Madhya Pradesh (undivided) in 1996-97 (Table.2). In 2015-16, similar situation (of C2 cost more than MSP) was observed in the case of Haryana, Madhya Pradesh (divided), Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh (divided) and West Bengal. Thus, in case of Andhra Pradesh and Assam, in 1996-97 C2 cost was more than MSP, but in 2015-16 C2 cost was lower than MSP indicating profitability of rice production in that year. In 2015-16, newly formed states Chhattisgarh and Uttarakhand were facing the situation of lower C2 cost compared to MSP, and were diverging from their parent states which faced C2 cost greater than MSP. Only Jharkhand was in convergence with its parent state i.e., Bihar in 2015-16, with C2 cost lower than MSP. On the whole it is observed that in 2015-16, rice cultivation was profitable with C2 cost lower than MSP in Andhra

Pradesh (undivided), Assam, Bihar (divided), Chattisgarh, Gujarat, Jharkhand, Karnataka, Punjab, and Uttarakhand. Then, why the area under Rice declined in Andhra Pradesh (undivided), Assam, and Karnataka? This might be due to the fact that MSP in India is not statutory and not effective in all states. Hence, another way of looking at economics of rice production is to compare realized price per quintal of output with C2 cost.

Table 2: Economics of Rice production in India in selected years in major rice growing states

States/Union Territories	C2 cost (Rs/q)		Yield (q/ha)		Realized price (Rs/ q)		Net-returns as percentage of total cost	
	1996-97	2015-16	1996-97	2015-16	1996-97	2015-16	1996-97	2015-16
Andhra Pradesh	405.82	1321.55	47.04	58.63	428.70	1429.75	5.56	8.20
Assam	401.22	1399.64	21.01	32.82	412.15	1048.80	5.03	-25.08
Bihar	377.16	1271.13	21.43	27.49	414.20	1140.74	9.78	-10.27
Chhatisgarh	na	1374.79	na	31.88	na	1242.33	na	-9.71
Gujarat	na	1097.31	na	43.17	na	1444.51	na	30.57
Haryana	424.68	1543.66	43.44	52.27	457.48	1708.73	7.72	10.76
Jharkhand	na	1349.11	na	21.77	na	1163.27	na	-13.74
Karnataka	na	1339.42	na	51.88	na	1728.39	na	27.47
Madhya Pradesh	389.44	1709.98	22.61	22.02	439.44	1355.45	12.77	-21.08
Maharashtra	na	2468.55	na	24.00	na	1922.05	na	-24.42
Odisha	365.02	1450.32	24.18	35.28	402.73	1106.84	10.42	-23.71
Punjab	344.81	1061.66	51.64	69.89	405.91	1494.20	17.76	40.74
Tamil Nadu	na	1435.17	na	49.13	na	1451.33	na	0.92
Uttar Pradesh	309.20	1541.04	34.02	35.85	398.51	1222.98	28.84	-20.42
Uttarakhand	na	935.36	na	47.24	na	1241.35	na	32.21
West Bengal	379.16	1423.29	37.20	44.91	427.35	1215.72	12.76	-14.80
Minimum Support Price	380	1410						

Source: DES, Cost of cultivation
na: not available

Based on analysis of cost of cultivation data, it is observed that in 1996-97, in all the states, realized price per quintal of output (which was computed by dividing total value of main product with derived yield) was more than MSP. In 2015-16, realized price per quintal of output was lesser than MSP in Assam, Bihar (divided), Chhattisgarh, Jharkhand, Madhya Pradesh (divided), Odisha, Uttar Pradesh (divided), Uttarakhand and West Bengal.

Highest difference between realised price and C2 cost per quintal paddy (i.e., profitability) was observed in case of Uttar Pradesh (undivided) in 1996-97 and Punjab in 2015-16. In Assam, Bihar (undivided), Odisha, and West Bengal (where rice area declined in 2016-17 compared to 1996-97), difference between realized price per quintal and C2 cost per quintal was negative. But in Andhra Pradesh (undivided), Karnataka, and Tamil Nadu the difference between realized price per quintal and C2 cost per quintal was positive. Hence, despite realised price per quintal was more than C2 cost, rice area decreased in these states.

Among the states whose rice area increased in 2016-17 compared to 1996-97, it was observed that difference between realized price per quintal and C2 cost per quintal in 2015-16 was negative in case of Chhattisgarh, Madhya Pradesh and Maharashtra. Thus, despite realised price per quintal was less than C2 cost, rice area increased in these state. On the other hand realized price was more than C2 cost per quintal in the case of Uttarakhand, but was less than C2 cost in the case of Uttar Pradesh (divided). However, in case of Haryana, and Punjab increase in rice area was associated with positive difference between realized price and C2 cost per quintal. Hence, only in some states, economics of rice production was associated with rice area expansion/decrease when analysis was based on per unit output basis.

In order to get further insights, analysis was carried out on area basis i.e., per hectare basis. In 1996-97, net returns were positive in all the states. But in 2015-16, in case of Assam, Bihar (divided), Jharkhand, Chhattisgarh, Madhya Pradesh, Maharashtra, Odisha, Uttar Pradesh (divided) and West Bengal net returns were negative (i.e., total returns were less than total costs). This could be the cause behind decreasing rice area between the selected years in Bihar (undivided), Odisha and West Bengal. In the case of Andhra Pradesh (Undivided) and Tamil Nadu, though total returns were more than total costs, net return share in total cost was very low. This might have led to decline in rice area in 2016-17 in these states. The way out for this is increasing realized price or reducing cost of production or increasing yield. From 2018 *kharif* onwards, GOI has started fixing MSP at 1.5 times (A2+FL) cost which is lower than C2 cost. Murali and Vijay (2017) reported higher share of land under pure tenancy in Andhra Pradesh (undivided), and Tamil Nadu. This by way of higher land rent (because of competition for land) might also contribute to higher cost of paddy cultivation in these states.

Table 3: State wise rice production and procurement details for selected years

States/Union Territories	**State rice area share in all India rice area (%)**		**State Rice production share in all India rice Production (%)**		**State rice procurement share in all India rice procurement (%)**		**Share of rice procurement in state rice production (%)**		**Rice procurement in 2016-17/ procurement in 1996-97**
	1996-97	**2016-17**	**1996-97**	**2016-17**	**1996-97**	**2016-17**	**1996-97**	**2016-17**	
Andhra Pradesh	9.46	4.89	13.07	6.76	34.92	9.77	42.35	49.99	0.82
Chhattisgarh	na	8.87	na	7.31	na	10.56	na	49.96	
Haryana	1.91	3.22	3.01	4.04	9.29	9.40	48.88	80.52	2.98
Madhya Pradesh	12.42	5.30	7.27	3.84	4.48	3.45	9.77	31.06	2.27
Odisha	10.29	8.98	5.43	7.61	3.67	9.53	10.72	43.32	7.63
Punjab	4.97	6.39	8.97	10.01	32.65	29.00	57.69	100.20	2.61
Tamil Nadu	5.00	3.33	7.10	3.67	5.69	0.38	12.71	3.56	0.20
Telangana	na	3.89	na	4.69	na	9.43	na	69.54	
Uttar Pradesh	12.78	13.08	14.40	11.76	7.02	6.18	7.73	18.18	2.59
Uttaranchal	na	0.60	na	0.57	na	1.85	na	112.06	
West Bengal	13.36	11.92	15.46	13.70	1.23	5.05	1.26	12.74	12.09
All India	100.00	100.00	100.00	100.00	100.00	100.00	15.86	34.59	2.94
Andhra Pradesh (Undivided)	9.46	8.78	13.07	11.46	34.92	19.21	42.35	58.00	1.62
Madhya Pradesh (Undivided)	12.42	14.17	7.27	11.15	4.48	14.00	9.77	43.45	9.2
Uttar Pradesh (Undivided)	12.78	13.68	14.40	12.33	7.02	8.03	7.73	22.53	3.36

Source: Computed using data from Agricultural Statistics at a glance
na: not available

In a recent study Bora *et al.* (2018) found that in states where public procurement of paddy is lower (Odisha, West Bengal and Uttar Pradesh), realised sale price of paddy was lower. Results of analysis of present study on dynamics of public procurement of paddy in 1996-97 and 2016-17 are presented Table 3. 1996-97, 11 major rice growing states in India, contributed 70 percent of rice area, 75 percent of rice production and 98.94 percent of public paddy procurement at national level. In 2016-17, the same states contributed 70 percent of rice area, 74 percent of rice production and 94.6 percent of public paddy procurement. In 1996-97, Andhra Pradesh was the major contributor (34.92%) in public procurement of paddy, followed by Punjab (32.65%) and Haryana (9.29%). But in 2016-17, Punjab was the major contributor (29%), followed by Chhattisgarh (10.56%) and Andhra Pradesh (divided). In all the 11 selected states quantity of paddy procured in 2016-17 was higher compared to 1996-97, except in Tamil Nadu. Share of paddy procured in state paddy production also increased in 2016-17 compared to 1996-97 in all paddy procurement states, except for Tamil Nadu. But, there were wide disparities in quantum of rice procurement. In Punjab and Haryana, share of paddy procured in total state paddy production was above 80% in 2016-17. This share was lowest in Tamil Nadu (3.56%) followed by West Bengal (12.74%). West Bengal, contributed 13.70 percent of country's paddy production, but its share in paddy procured in the country was only 5.05 percent in 2016-17. Similar situation was observed in case of Tamil Nadu also. No paddy procurement was reported from Assam, Bihar, Jharkhand, Karnataka, and Maharashtra states separately, which together contributed 24 percent of paddy production in the country. This lower and lack of procurement could have led to lower price realization by farmers in Assam, Bihar, Odisha, and West Bengal (due to lack of competition from public sector), there by leading to decrease in paddy area. Karnataka and Maharashtra are the exception where in, despite no procurement is reported separately, price realized for paddy was higher than MSP. But in Maharashtra, though realized price was lower than C2 cost, still paddy area in the state was increased in 2016-17 compared to 1996-97.In contrast, in Karnataka though realized price was higher than both MSP and C2 cost, but area under rice decreased in 2016-17 compared to that in 1996-97.

As stated earlier India is the largest exporter of rice. In India, there was a ban on export of non-basmati rice from 15th October 2007, and was replaced with Minimum Export price on 31st October 2007. In between there were several policy changes like ban on export of non-basmati rice from central pool, total ban, etc. The ban on export of non-basmati rice from India was lifted in September 2011 allowing private parties to export from their privately held stocks under Open General Licence (OGL). Basmati rice in India is protected under Geographic Indication (a kind of Intellectual Property rights) and the certification is limited to Punjab, Haryana, Himachal Pradesh, Delhi, Western Uttar Pradesh, Uttarakhand and two districts of Jammu and Kashmir. It was observed that export price of rice from India was higher than domestic wholesale price of rice during 2013-2017 (CACP, 2018). This might have also influenced rice area expansion in Punjab, Haryana and Uttarakhand. Murali and Vijay (2017) reported that "land hunger" of agricultural labour through the tenancy market is constraining crop diversification in some states. Hence, tenancy market might also be a factor determining extent of rice area in some states.

Emerging sustainability Issues and options available:

a) Stress on water resources

Till now in India, increasing rice production per unit area was the focus of research and input subsidy polices. This has led to a situation of depleting water resources. Kampman (2007) estimated that during 1997-2001, share of water foot print of paddy production in total crop water print in India as 39.3 percent. Sharma *et al.* (2018), estimated the total consumptive water use of rice production in India per year as 221 BCM. Chapagain and Hoekstra (2011) estimated water foot print for producing rice in India as 2020 m^3 per tonne of rice and a percolation loss of 1403 m^3 per tonne of rice. Depleting water resource has now led to shift in focus to increasing rice production per unit of water. Decline in paddy area observed (in 2016-17 compared to 1996-97) in the current study with respect to Andhra Pradesh (undivided), Karnataka, and Tamil Nadu is in line with water saving objective (as these states are experiencing) water stress. But the expansion in paddy area observed (in 2016-17 compared to 1996-97) in Maharashtra, Haryana, Punjab, and Gujarat is not desirable from the perspective of water saving (as these states are also experiencing water stress). Hence for addressing mismatch between the hydrological suitability and rice cropping pattern in India, several policy measures are being suggested.

Najmuddin *et al.* (2018) in the case of Bihar reported that water productivity for rice varied with season and increased with proportion of irrigated area in total rice area. Mohanty *et al.* (2017) suggested that eastern India which has the majority of rainfed rice ecosystems, could be prioritized to intensify rice production. Based on analysis of state level water productivity of rice in physical terms Sharma *et al.*(2018), observed highest irrigation water productivity (0.75 kg/ m^3 irrigation water applied) in Jharkhand and lowest productivity in Maharashtra (0.17kg /m^3 irrigation water applied). They also analysed irrigation water productivity of rice in economic terms, reported highest water productivity of rice in Chhattisgarh (11 Rs/m^3 irrigation water applied) and lowest water productivity in Maharashtra (2.75 Rs/m^3 irrigation water applied). Hence, they suggested that paddy cultivation in Maharashtra need to be discouraged except in small Konkan belt. They also observed that in states of Punjab and Haryana, though land productivity was high, water productivity of rice was lower despite having 100 percent irrigation. Further they observed that Punjab, where area under rice was less than many states, emerged as the third highest water consuming state. Hence, Sharma *et al.* (2018), suggested crop diversification in Punjab and Haryana states. These two states together with Western Uttar Pradesh have been identified as the water stress hot spots globally also (OECD, 2017).

Sharma *et al.* (2018), reported that states with higher irrigation water productivity have yet achieved only lower irrigation levels due to regionally skewed policies for agriculture in India. They inferred that imperfect water pricing policies, skewed procurement policies, inadequate electricity supply and input subsidies have led to mismatch between the hydrological suitability and rice cropping pattern in India. Joshi *et al.* (2018) reported that in Punjab, "varietal stickiness" i.e., inertia to change from long duration Pusa-44 variety rice was due to combination of 3 factors *viz*., higher yield of the variety, assured procurement and tariff free electricity. Srivatsava *et al.* (2017) estimated that withdrawal of energy subsidy, will lead to 29 % groundwater saving in Punjab. For improving water productivity Sharma *et al*. (2018) suggested a move from price policy approach of heavily subsidizing inputs to directly depositing money in the bank account of farmers on per hectare basis, leaving input prices to be determined by market forces. They suggested future water productivity studies, incorporating the state-wise cost of irrigation water applied.

Gill *et al*. (2018) in the context of Haryana, reported that in the case of paddy cultivation, the actual number of irrigations has been between 2 and 2.5 times of the optimum number of irrigations by electricity-operated tube wells and diesel-operated pumpsets. They suggested that in certain agro-climatic zones where rainfall is less and land is sandy, the electricity subsidy can be completely withdrawn for the irrigation of paddy crop, as a measure to save water and energy. They also suggest that subsidy can be redesigned, and can be divided according to average cultivated area, so as to make it equitable and save water.

Sreevidhya and Elango (2019) estimated that by means of rice exports, India has Virtual Water (VW) export of 195.61 Gm^3 during 2006-07 to 2015-16. They have considered virtual water content of rice (i.e., water required in the production of rice) as 2850 m^3 per tonne of rice and observed that the highest VW export from India was through rice (among crop and livestock products). They have estimated virtual water import by India in the form of rice import as 0.024 Gm^3 during 2006-07 to 2015-16. In India on rice import an import duty of 70-80 percent is there. It is being opined that rationalization of import duty on rice import can support crop-diversification. Chapagain and Hoekstra (2011) opined that in international context as irrigation systems are generally heavily subsidized and water scarcity is never translated into a price, the economic or environmental costs are not contained in the price of rice. Sreevidhya and Elango (2019) suggested that agricultural products that are produced by stringent water efficient methods only need to be encouraged for exports.

In rice several water saving technologies like System of Rice Intensification (SRI), Direct Seeded Rice are being advocated. Though these are water saving technologies, several adoption constraints like scarcity of skilled labour (in the context of SRI), yield reduction (in the case of DSR) are reported by some studies (Dharmendra *et al.*, 2017 and Devi *et al.*, 2017). Further, instead of promoting DSR as water saving technology in water safe area (as a water conservative measure), is being promoted in water stressed areas, i.e., parts of Andhra Pradesh and Karnataka as a stress coping mechanism. In states like Punjab use of DSR is rather a response to labour scarcity than response to water stress.

b) Green House Gas (GHG) emission

Vetter *et al*. (2017) reported that in India highest GHG emission was associated with rice production when compared to other crops. Methane is the main GHG associated with rice production and methane is a short lived GHG. Some studies indicated that Methane emission in rice production can be reduced by water management i.e., by practicing intermittent irrigation in place of continuously flooded system. However, some studies (Kritee *et al*., 2018) reported that nitrous oxide (a long lived GHG) emission may increase under intermittent irrigation. This is indicating trade-off between emission of methane and nitrous oxide. Kritee *et al*. (2018) based on evidences from their study results across three agro-ecological regions in India, suggested that co-management of water with inorganic nitrogen and/or organic matter inputs can decrease climate impacts caused by GHG emission. Shift to rice varieties with lower GHG emission such as short duration varieties, hybrid rice varieties is also being viewed as an option (McFadden *et al*., 2013). Harnessing consumer willingness to pay premium price for rice that has lower GHG emission is also being viewed as option to promote adoption of rice cultivation practices with low GHG emission (Akaichi, 2017).

From the discussion in the preceding paragraphs, it is evident that multiple sustainability issues are associated with paddy cultivation. As a response to address these sustainability issues, first Standards for sustainably produced rice was released in 2015 by the Sustainable Rice Platform (SRP). The SRP is a multi-stakeholder platform convened by the UN Environment and the International Rice Research Institute (IRRI) in order to promote resource use efficiency and sustainability in the global rice sector. As of January 2019, 97 members (agricultural research institutions, agri-food business, public sector and civil society organizations) are there in SRP including some from India.

SRP Standards are indicators (Table 4) for economic, environmental and social sustainability, based on which a country can evaluate sustainability of its rice cultivation (practices) and value chain, and target improvement over years. However exact desirable/optimal values for some indicators need to be decided at country level or sub national level based on agro-ecological conditions, taking into consideration the possible trade-off between different indicators. These values have to be decided with multi-stake holder participation.

Table 4: Performance indicators for sustainable rice cultivation

Indicator Number	Indicator	Unit	Desirable movement direction over years
1	Profitability: net income from rice	Income/ha/year	Increase
2	Labor Productivity	Net income from rice/ number of human labour days	Increase
3	Productivity	Kg/ha	Increase
4	Food safety	Percentage of milled rice that falls within safety requirements for heavy metals, pesticide residues and mycotoxins	Increase
5	Water use efficiency	Yield per unit of water	Increase
6	Nutrient use efficiency-N	Yield per Kg element of N	Increase (provided farmers do not mine their soil)
7	Nutrient use efficiency - P	Yield per Kg element of P	
8.	Pesticide use efficiency	0-100 score based on answers to a set of questions related to pesticide usage practices and outcomes	Increase
9	Green House Gas emission	Amount of methane emitted per unit of land	Decrease
10	Health and safety	0-100 score based on answers to a set of questions related to practices and outcomes	Increase
11	Child Labour	0-100 score based on answers to a set of questions related to practices and outcomes	Increase
12	Women's empowerment	0-100 score based on answers to a set of questions related to practices and outcomes	Increase

Source: SRP(2015)

Smith *et al*. (2019) demonstrated the potential of a VSS (Voluntary Sustainability Standards) in sugarcane to reduce eutrophication, water use, greenhouse gas emission and natural ecosystem conservation. VSS are stakeholder derived principles with measurable and enforceable criteria to promote sustainable production outcomes, may be an effective way to reduce the negative impacts of agriculture. Since sugarcane happens to be a commercial crop, with strong linkages in the value chain, VSS will be relatively easy for implementation. But in rice, the situation is different. However, increasing consumer concern for food safety, preference for eco-friendly agriculture is being viewed as opportunity for promoting sustainable cultivation practices in rice also. Nguyen *et al*. (2018) tested the feasibility of a market based incentive mechanism by eliciting consumers' willingness to pay for rice produced and labelled under national sustainable production standards in Vietnam. They reported that, domestic consumers were willing to pay 9 percent premium for certified sustainably produced rice. This premium price will incentivize adoption of sustainable rice production standards by farmers. Demont and Rutsaert (2017) suggested three strategies to make rice value chain more sustainable *viz*., (i) embodying sustainability in the product through certified sustainable production labels, (ii) internalizing sustainable production through vertical co-ordination (like contract farming) and (iii) disembodying sustainability through book and claim certificate trading(which is adopted presently in the case of palm oil). Recently Indigo agriculture and Anheuser-Busch (in U.S) announced partnership for sustainable rice production(Seed World). Besides market based approach, State intervention for promotion of integrated technology packages through a policy can also be one option for sustainable rice production as was observed in Vietnam (Stuart *et al*. 2018).

Conclusions

The present study is based on observations at state level, at two points of time. It is observed that rice dynamics in India is not in line with observed economics of rice production in some states. Micro-level studies extending the analysis to district level, covering entire rice value chain may yield insights regarding deviations observed with respect to some states. However, multiple sustainability issues are emerging in rice cultivation as there is mismatch between the hydrological suitability and rice cropping pattern in India. In order to address these issues several policy options (like rationalization/removal of power subsidy, crop-diversification, rationalization of rice export-import policy) and technological options (like SRI, alternate wetting and drying, DSR, switching to short duration varieties, co-management of irrigation and nutrients) are being suggested. However, all these options are focussing on any one individual sustainability issue only but not all. For addressing several sustainability issues simultaneously, Standard for sustainably produced rice developed by SRP can be a framework. Following this framework, there is need for India also to develop standards for its rice production. Policies, technological options and future research on rice need to be aligned towards the so developed standards. Besides that there is urgent need for delineating areas for paddy cultivation based on hydrological suitability.

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