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A Contemporary Overview of Agricultural Productivity: Trends, Challenges and Lessons for India

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Abstract: India agriculture has been experiencingdecliningproductivity rates owing to a misallocation of resources in the domain of agriculture. Despitevarious interventions and policies adopted by the government , the benefits have been limited to certain pockets of India. This has slowed the pace of growth of agricultural productivity. The paper examines the trends of agricultural productivity of India in the global scenario. The importance of irrigation in productivity has been established by drawing inter-state disparities in rice production of India and analysing the irrigational scenario in India. It has also been foundthat a higherlevel of farmmechanisation corresponds to a greaterproductivity, through an inter-state comparison of yield of wheat and an analysis of the global scenario.The important aspects of the R&D scenario arebrought out through a inter-country examination of investment trends. The weakness of the Indian agricultural R&D isportrayedthroughanalysing the budgetallocation and researchintensity. The innovative solutions to bolsterproductivityisshownthrough case studies on four countries. The contractfarming in Indonesia , PPP(Public-Privatepartnership) for agricultural R&D in Egypt ,and desalination of water for irrigation in Spain are discussed to highlight the need for a paradigm shift fromtraditionalmodels to contemporarymodels for increasing agriculture productivity.

Key Word: yield ; irrigation ; mechanisation; research and development ; contractfarming ;

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I. INTRODUCTION

The realization of SDGs(Sustainable Development Goals) , SDG- 1(no poverty) , SDG-2(zero hunger) and SDG-8(decent work and economic growth) will lead to higher demand for agricultural output in developing countries, which suffer from lowproductivity and food production .The yields of major crops (vegetables, roots and tubers, pulses, sugar crops, oil crops and cereals) vary substantially across different regions of the world. The estimated yield gaps in low-income countries exceed 50%, highlighting their inability to achieve their potential. It is largest in sub-Saharan Africa (76 percent) and lowest in East Asia (11 percent). There are also very large disparities in crop yields between high- income and low-income countries. The yield of rice and wheat in low-income countries is almost half of that in high-income countries. India is an agrarian economy with agriculture providing employment to almost 43% of the Indian population. However,

the growth of GVA (Gross Value added) of agriculture and allied sectors has remained fairly volatile with variations of -0.2% in 2014-15 to 6.3% in 2016-17, and then declined to 2.8% in 2019-20. These persistent fluctuations point towards the agrarian distress and absence of an appropriate government intervention. Despite the huge employment, the contribution of the sector to the Gross Domestic Product (GDP) declined from 54% in 1950-51 to 15.4% in 2015-16 , partly due to sectoral change. India has remained fairly consistent in exporting agricultural commodities with variations ranging from 1.7 in 2010 to 2..2 in 2017. Although theagricultural yield of food grains has increased by more than four times since 1950-51, and was 2,070 kg/hectare in 2014-15, India has considerably lagged behind in terms of agricultural productivity. The rapid strides after green revolution should be supported through a paradigm shift in approach towards productivity. Examining the current scenario, the opportunity cost for low agricultural productivity is very high, and allocative efficiency is the need of the hour. The paper attempts to analyze (a) agricultural productivity in India(b) relationship of irrigation with agricultural productivity (c)impact of R&D and mechanization on agricultural productivity (d)lessons globally (e) way forward

II. AGRICULTURAL PRODUCTIVITY OF INDIA

Agricultural productivity is one of the primary factors of income growth. In a country , where land is scarce and there is an abundant presence of small and marginal farmers as well as small land holdings (due to inheritance of land over years) , agricultural productivity is crucial for the upliftment of the poor farmers .

The line graphs above(figure-1 and figure-2) shows a comparison of India's yield of cereals and vegetables over 50 years with the yield of Brazil , China , and the average world rate. From figure 1 and figure 2, it can be deduced that India has considerably lagged behind countries like China and Brazil in terms of agricultural productivity. It can be seen that Brazil and China were able to increase their productivity from the 1980s , however India's productivity for major crops like cereals and vegetables is consistently below the world yield. In addition , it can be observed that the crop yields have also remained unstable over thelast two decades. It is seen that the slope depicting India's productivity is much flatter when compared to that of other developing countries like Brazil and China.To sum up , agricultural productivity has consistently increased from 1970s due to green revolution but has remained highly unstable due to negligence on other factors determining productivity.

Figure 1: comparison of yield of cereals

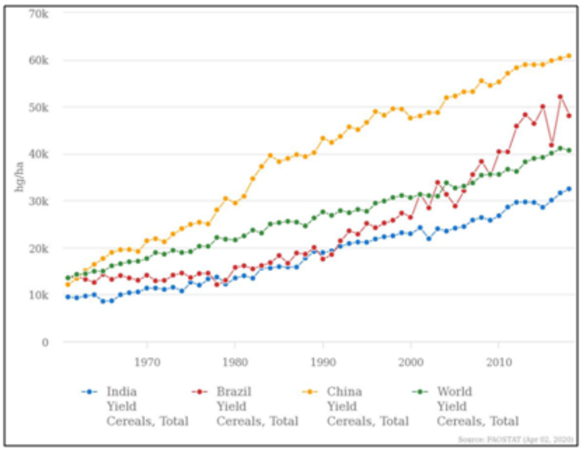
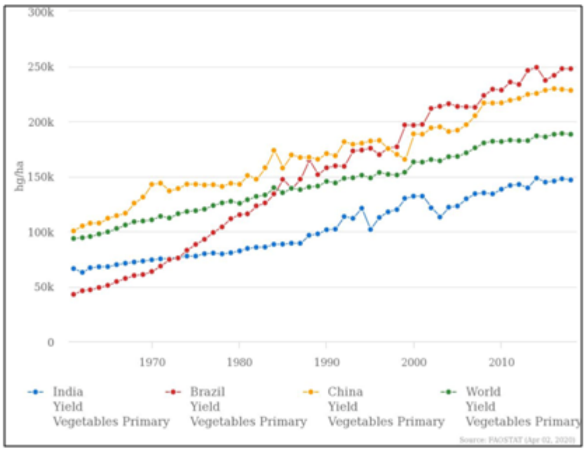


Figure 2: comparison of yield of vegetables

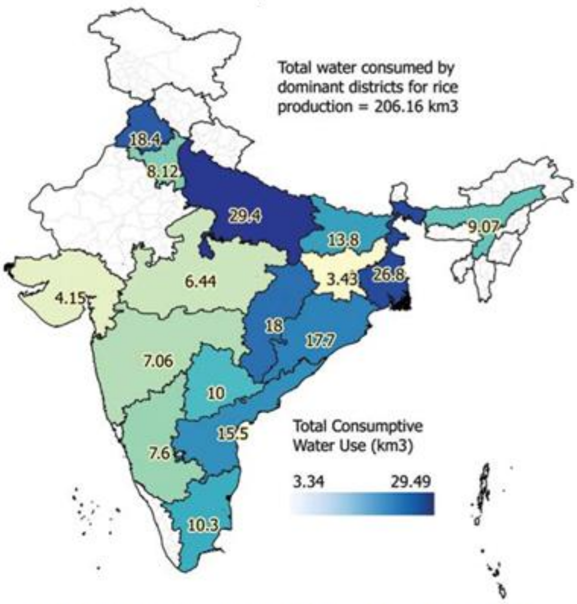


III. IRRIGATION AND AGRICULTURAL PRODUCTIVITY

Irrigation is one of the foremost factors that impacts agricultural productivity. It has been found that the productivity is remarkably higher in the areas that depend less on rainfall and have substitute sources for supporting the cultivation. Access to irrigation can be credited as one of the major factors for the success of green revolution in India. This relationship between irrigation and productivity can be examined by considering the rice cultivation in different states of India that experience regional disparities in terms of irrigation. The map shows the consumption of water in the different states of India.

The distribution depicted in the map (Figure-3) shows the disparities in the distribution of irrigation in different states of India. It can be clearly seen the states of Uttar Pradesh, West Bengal, Punjab consume the highest amount of water for irrigation, while states like Bihar, Odisha, Telangana, Assamhave substantially lower consumption. Table-1 shows the area under rice cultivation in the states having one percent of the rice cultivated area. The data indicates that traditional rice producing states Odisha, WestBengal, UttarPradesh, Telangana have the highest area under rice cultivation (with area under cultivation more than 40l ha) whilst stateslike Punjab, Tamil Nadu comparatively lower figures in the year 2010-11.Table-2 shows the rice production of the states that are dominant rice producers It is evident from table-2 that the states of West Bengal, Uttar Pradesh , Punjab are the largest producers of rice in while the states of Madhya Pradesh, Jharkhand and Gujarat are the lowest producers of rice in 2010-11. According to the map and tables showing figures for the year 2010-11 , it can be observed that despite Punjab having asubstantially low area under rice (26.9 l ha) is one of the dominant producers of rice , producing 105.52 lakh tonnes with a very high irrigation per hectare. In addition, the states of Uttar Pradesh and West Bengal have a high area of land under rice cultivation , coupled with intensive irrigation , making them the dominant producers . In contrast, Odisha (41.2 l ha) and Telangana (46.77 l ha) having a large area under rice cultivation are failing to provide adequate irrigation to the crop, resulting in lower production. This comparison points that irrigation is an underlying factor for agricultural productivity.

Figure 3:the consumption of water in different states for rice production



Source: WATER PRODUCTIVITY MAPPING of MAJOR INDIAN CROPS (2018- NABARD)

Table 1: States with at least one per cent of India's rice cultivation area (lakh ha) and their respective dominant rice growing seasons (2010-11)

States	Area under rice (l ha)	States	Area under rice (l ha)
West Bengal	53.9	Assam	23.7
Uttar Pradesh	55.3	Bihar	28.4
Punjab	26.9	Karnataka	14.4
Andhra Pradesh	24.4	Haryana	11.7
Odisha	41.2	Maharashtra	14.1
Tamil Nadu	17.9	Madhya Pradesh	15.1
		Gujarat	7.2
Telangana	46.77	Jharkhand	8.7

Source: WATER PRODUCTIVITY MAPPING Of MAJOR INDIAN CROPS (2018- NABARD)

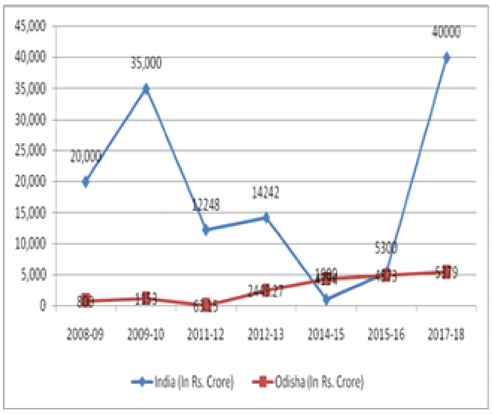
The data in table-3 shows how Punjab (98%), Uttar Pradesh (76.1%),Haryana (88.9%) have the highest percentage of irrigated area that accurately reflects in their high contribution towards the total production in India in comparison to other states. It can be seen that the north-eastern state of Assam (4.6%),Jharkhand (7%) with low percentage of irrigated area contribute 2.01% and 1.7% respectively towards the total production and also experience lower yields.The northern states have high intensity in irrigation, at times crossing 75 % which has been made possible through incentives provided by the government (free electricity for pumping water in Punjab) . In addition to rich groundwater sources, Uttar Pradesh,Punjab, and Haryana also benefit from the presence of perennial rivers and an efficient canal irrigation.However, the Eastern, Northeastern and southern states depend on monsoon in the absence of adequate irrigation infrastructure to support irrigation, with irrigation varying from 0% to 60%. In figure-4, all India allocation experienced a sharp decline during 2011-12 and 2014-15, 2015-16, only to be revived during 2017-18. In case of Odisha, however, it has been a steadily rising curve, though it's not adequate as only 33% of Odisha's agricultural land is irrigated, as against an all India average of 44% and as high as more than 90% in some northern states. This shows that the state and central should ensure adequate investments in agricultural infrastructure in states like Odisha, Telangana, Bihar etc.

Table 2: Production of dominant states in rice production in lakh tonnes (2010-11)

Rank	States	Production, lakh tonnes	Rank	States	Production, lakh tonnes
1	West Bengal	130.53	9	Assam	44.59
2	Uttar Pradesh	116.43	10	Bihar	36.85
3	Punjab	105.52	11	Karnataka	36.60
4	Andhra Pradesh	74.17	12	Haryana	34.17
5	Odisha	71.98	13	Maharashtra	17.47
6	Tamil Nadu	53.63	14	Madhya Pradesh	14.69
7	Chhattisgarh	52.82	15	Gujarat	14.24
8	Telangana	46.77	16	Jharkhand	10.50

Source: WATER PRODUCTIVITY MAPPING Of MAJOR INDIAN CROPS (2018- NABARD)

Figure 4: Allocation to Irrigation by India and Odisha in the Last Decade



Source: Union Budget for India and State Budget [9] & [10]

Table 3: Production , yield ,irrigated areas of some Indian states

State	Area (m. hectares) (2013-14)	%of India (2013-14)	Production (million tons) (2013-14)	%of India (2013-14)	Yield (kg per hectare) (2013-14)	% area irrigated (2011-12)
Uttar Pradesh	20.23	16.05	50.05	18.90	2474.00	76.10
Punjab (northern India) (northern India)	6.560	5.20	28.90	10.92	4409.00	98.70
Madhya Pradesh (central India)	14.94	11.85	24.24	9.50	1622.00	50.50
Andhra Pradesh	7.61	6.04	20.10	7.59	2641.00	62.50
Rajasthan	13.42	10.64	18.30	6.91	1364.00	27.70
West Bengal	6.24	4.95	17.05	6.44	2732.00	49.30
Haryana	4.40	3.49	16.97	6.41	3854.00	88.90
Maharashtra (western India) (western India)	11.62	9.22	13.92	5.26	1198.00	16.40
Bihar (eastern India) (eastern India)	6.67	5.29	13.15	4.97	1971.00	67.40
Karnataka	7.51	5.95	12.17	4.60	1622.00	28.20
Tamil Nadu	3.55	2.81	8.49	3.21	2396.00	63.50
Odisha	5.15	4.09	8.33	3.15	1617.00	29.00
Gujarat (Western India) (Western India)	4.29	3.40	8.21	3.10	1917.00	46.00
Chhattisgarh	4.95	3.93	7.58	2.86	1532.00	29.70
Assam	2.53	2.01	4.94	1.87	1952.00	4.60
Jharkhand	2.24	1.77	4.19	1.58	1874.00	7.00
Uttarakhand	0.89	0.71	1.78	0.67	2001.00	44.00
Others	3.26	2.59	6.38	2.41		-

Source: Study of water and agriculture 2017 -Dr Vibha Dhawan

IV.FARM MECHANISATION AND AGRICULTURAL PRODUCTIVITY

Farm mechanization in India is about 40-45 percent, which is still low when compared to countries such as the US (95 percent), Brazil (75 percent) and China (57percent). Although mechanization has increased since the last few decades, as an agrarian economy India should further increase this mechanization, The farm power availability on Indian farms has grown from 1.47 kW/ha in 2005-06 to 2.02 kW/ha in 2013-14. The shift from a labor-intensive farming to a farming involving farm mechanization can greatly decrease the disguised unemployment and underemployment in the sector, increasing the efficiency of the factors of production.

Figure 5: India relative development of mechanisation

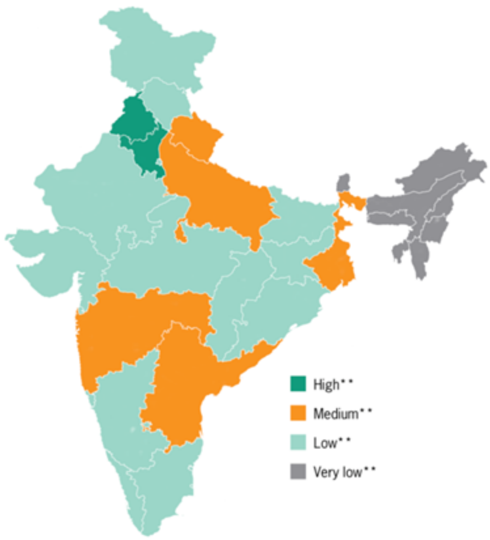


Figure 15: India relative development of mechanisation
Source: State of Indian Agriculture, Department of Agriculture report, 2012-13
** Based on relative scale of farm power availability as shown in the report

Table 4:Wheat production of the states dominant in its production

State	2017-18#				
	Area	% to All - India	Production	% to All - India	Yield
(1)	(2)	(3)	(4)	(5)	(6)
Uttar Pradesh	9.75	32.98	31.88	31.98	3269
Punjab	3.51	11.86	17.85	17.90	5090
Madhya Pradesh	5.32	17.97	15.91	15.96	2993
Haryana	2.53	8.55	11.16	11.20	4412
Rajasthan	2.81	9.50	9.19	9.22	3270
Bihar	2.04	6.89	5.74	5.76	2816
Gujarat	1.06	3.58	3.10	3.11	2932
Maharashtra	0.92	3.11	1.62	1.62	1761
Uttarakhand	0.33	1.13	0.91	0.91	2727
Himachal Pradesh	0.34	1.14	0.59	0.59	1734
Others	0.97	3.29	1.75	1.76	@
All India	**29.58**	**100.00**	**99.70**	**100.00**	**3371**

Source: Directorate of Economics and Statistics, DAC&FW

It can be seen in the map(figure-5) that the northern states of Punjab, Haryana ,and Uttar Pradesh, West Bengal, Andhra Pradesh and Maharashtra have relatively a higher degree of farm mechanization than the other states of India. The states of Punjab and Haryana have the highest intensity of mechanization whereas the north-eastern, southern states along with Madhya Pradesh and Rajasthan are essentially lagging behind.It can be determined from the table-4 that in 2017-18, the states of Uttar Pradesh (31.98%) , Punjab(17.85%) and Madhya Pradesh (15.91%) are the largest producers of wheat. This can be closely linked to the extent of farmmechanisation in the respective states.It can be clary seen that Rajasthan (9.50%) and Haryana(8.55%) have marginally differing area under wheat but the production varies by almost 2%. Although Madhya Pradesh is one of the largest producer by the virtue of the area under cultivation (17.97%) , its productivity level is lower than that of Punjab (11.86%) which has a lesser area under cultivation. In addition this trend can been seen to persist also on the states of Bihar and Haryana where the difference between production is almost 6%..This establishes a positive correlation between the farm mechanisation and agricultural productivity. It throws light on the fact that states that have made rapid strides in ensuring a greater level of farm mechanisation have been able to successfully increase their yields, thereby increasing agricultural productivity. This helps in ensuring that the scarcity of land can be compensated through a greater mechanisation that would certainly increase the yield. In India, the level of mechanisation varies greatly by region. States in the north such as Punjab, Haryana and Uttar Pradesh have high level of mechanisation due to appropriate governments interventions in these states that have ensured the timely support in promotion of mechanisation of farms. The western and southern states in the country have a lower level of mechanisation due to the smaller and scattered land holdings. This has reduced the profitability of mechanisation in these states thus reducing the its degree. In north-eastern states, the level of mechanization is extremely low. Factors such as hilly topography, high transportation cost, lack of state financing and other financial constraints due to socio-economic conditions and dearth of agricultural machinery manufacturing industries have stunted the growth of agriculture in these states.

The line graph above (figure-6) shows this positive dependence of agricultural productivity on farm. It can be determined from the graph that yield per hectare experiences a steep rise as the farm power, or the degree of farm mechanisation increases. From the 1990-2011 , an increase in farm power from a little below 1kW/ha to a little less than 2kW/ha resulted in the crop yield increasing from around 1000kg/ha to around 2000kg/ha .Farm mechanisation is a relief to the farmers in the dearth of land and water , which helps to increase the efficiency of the inputs of production.

Figure 6: Relationship between farm power and productivity

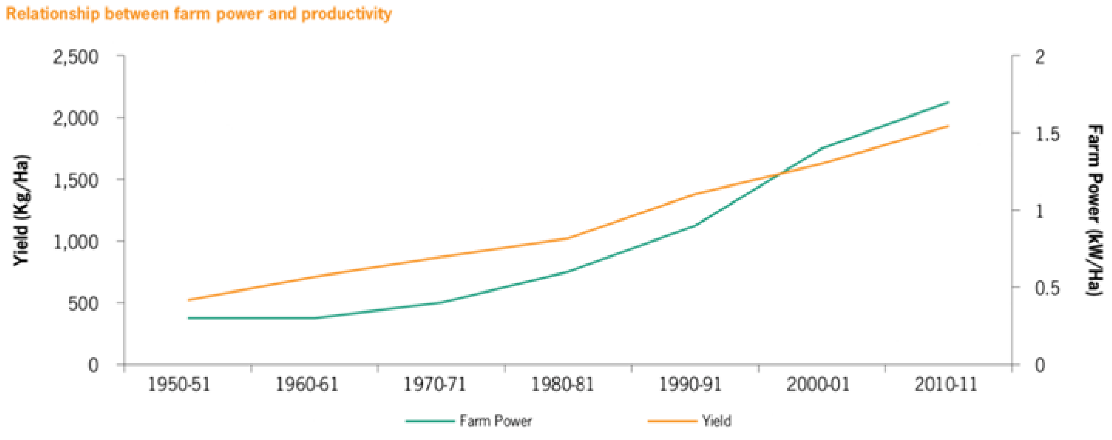


Figure 8: Relationship between farm power and productivity
Source: Ministry of Agriculture

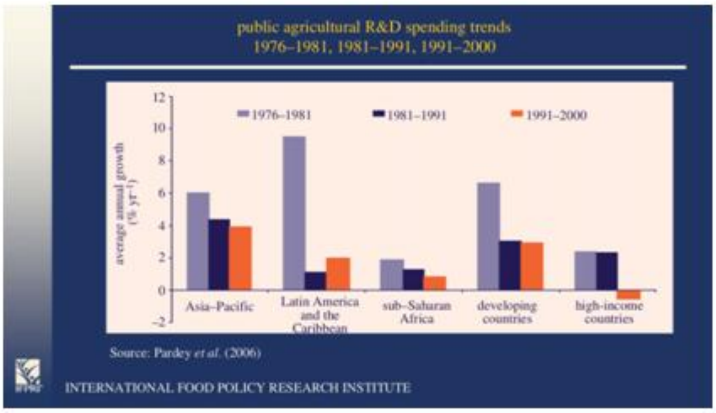
The experience of developed countries reflects that their investments on farm mechanisations have had a profound impact on the agricultural productivity. These countries have efficiently embraced the advancements in farm mechanisations and have ensured adequate incentives required to carry out various levels of mechanisation.Canada has mechanised almost 90% of its agricultural sector that has had a positive growth in the levels of productivity. Farmers in the USA make huge capital expenditures on farming, which has resulted in a capital-intensive farming with 95% mechanisation (advanced equipments and machinery) , that accurately translates into higher yield. France boasts a 99 percent level of mechanisation , along with the presence of a large number of mechanised farms. China has around 60 percent of farm activities mechanised that complements in investments in other factors of production. Japan is one of the most agriculturally mechanised nations in Asia Pacific region , boasting levels of mechanisation that are at par in levels of that of USA and UK.

Figure 7: Yield per hectare

V. RESEACRH AND DEVELOPEMENT

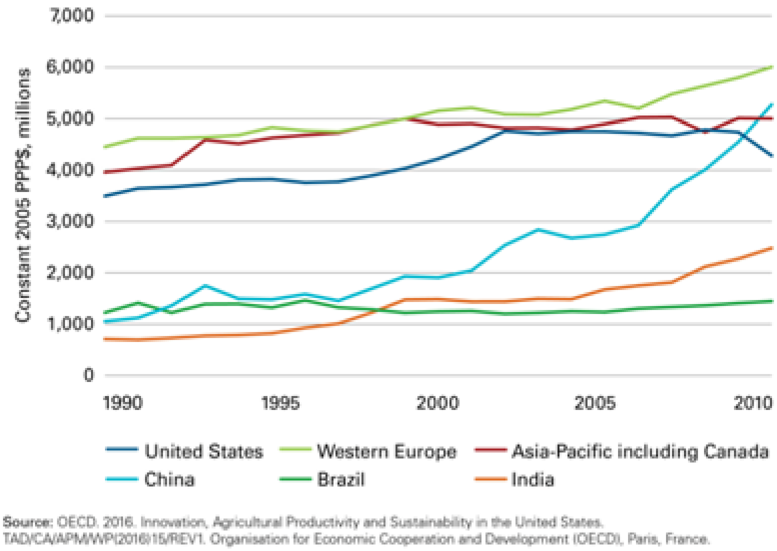
Agricultural science has always played a central role in economic progress . Agricultural research has greatly facilitated lower food prices to domestic population, improved nutrition, expansion in rural employment, agricultural exports and enhanced level of foreign exchange, competitiveness of agricultural commodities in the world markets .

Figure 8:R&D spending trends



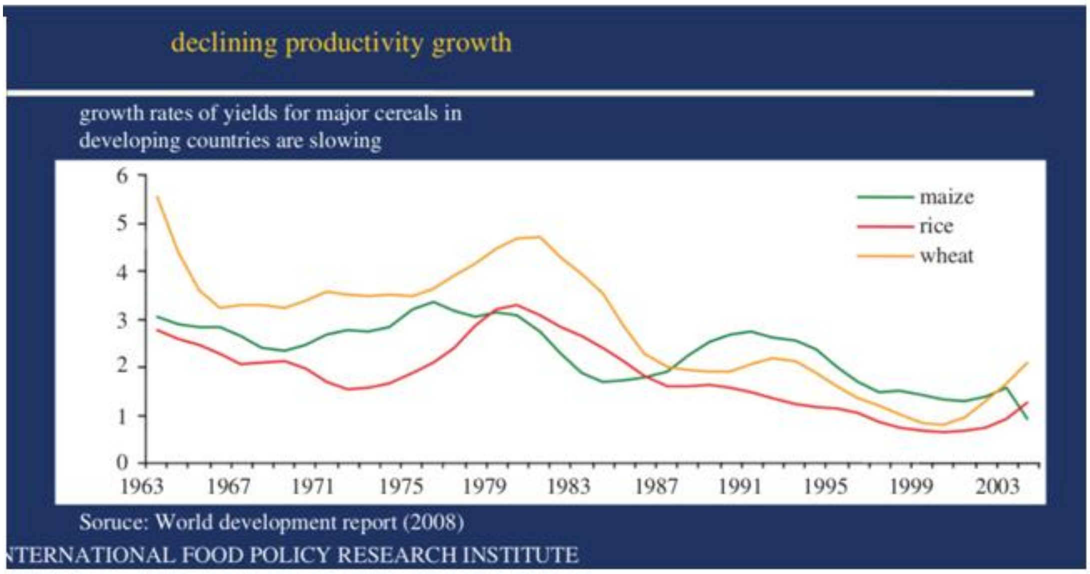
In figure-8, it can be seen that that the growth in government funding in agricultural R&D has experienced a sharp decline all over the world. In addition, The growth in funding has suffered a tremendous decline in developing countries from around 7% in 1976-1981 to less than 4% in 1991-2000 . The figure-10 shows that the growth rate of productivity levels of important crops like maize , rice and wheat have remained unstable . Moreover , the decline the public funding from 1991-2000 coverts to a low growth in productivity levels after

Figure 9: national agricultural R&D expenditures1990-2010



1990s.It can be observed(figure-9) that Western Europe and China have the highest spending on agricultural research and development.The spending of china on R&D has grown exponentially from a little over US$1000 million (1990) , to more than $5000 million (2010). It can be seen that India's investment has has consistently increased from from less than US$1000 million in 1990, to more than US$2000 million in 2010. However it can be seen that its' slope is much flatter in comparison to other countries , highlighting the trend of lower investments in comparison to developed countries.

Figure 10: declining productivity growth



Although India's investments in research and development has consistently risen over the years, the distribution of spending shows the disparities in the spending on salary , and operations and programs and capital investments.The figures give an evident relationship between the frequency of advancements and the spending. Almost 80%(figure-11) of the spending goes in paying salaries , leaving a much lower proportion of the spending for research opportunities. .It can be concluded that there is a misallocation and inefficiency in the funding of central and state governments towards research and development , which has stunted the growth of major scientific breakthroughs in the field of agriculture. Budget deficits and bureaucracy cause delay in channelling the funds from the respective state governments.Low capital intensity is preventing adequate operational back up to scientists and provision available for infrastructure is hardly sufficient to meet the maintenance of the existing infrastructure and modernisation of research infrastructure , resulting in a slower pace of research.

Figure 11: distribution of agricultural R&D spending

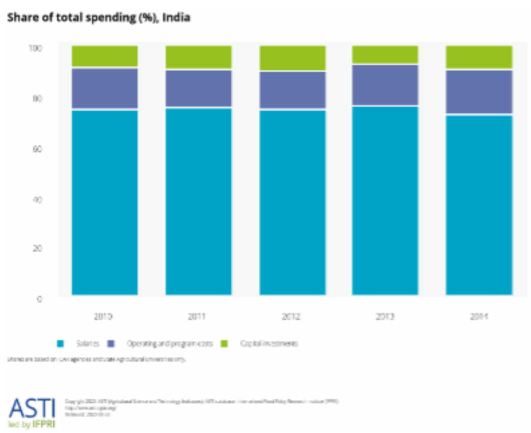
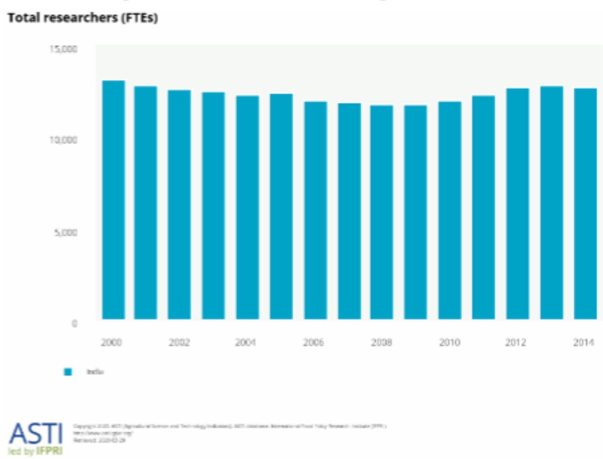
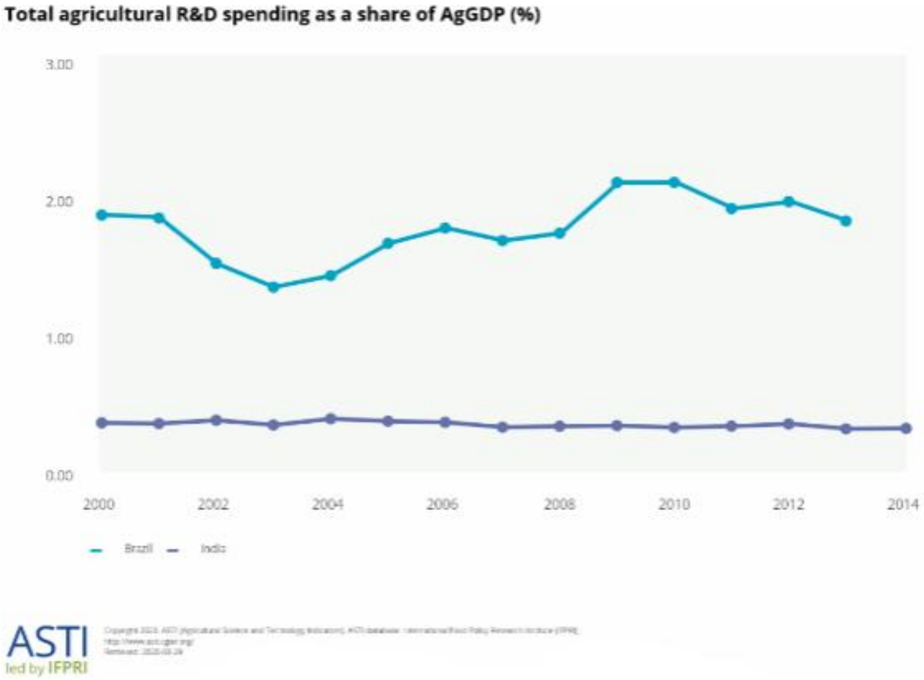


Figure 13: the number of researchers in agricultural R&D



When we compare the research and development scenario of India with Brazil) figure-12), it can be seen that India falls behind in terms of agGDP or the number of researchers per 100,000 farmers. In 2013 , Brazil had an agGDP of 1.82% while India had an agGDP of 0.30. This offers evidence that India falling a short of an acceptable number of researchers in this field and has a lower research intensity than some developing countries like Brazil etc.The low and stagnant agGDP is also reflected by a stagnant number of researchers (around 14,000) in the field of agriculture (figure-13). It is a reflection of the poor contribution in the domain of research.The rapid strides made after the green revolution has led to a huge growth in productivity but this productivity has remained stagnant and unstable over the last two decades, resulting in underperformance

Figure 12: AgGDP comparison of Brazil and India



VI.GLOBAL LESSONS

(A)<u>INDONESIA</u>

Figure 14: the comparison of rice production in India and Indonesia

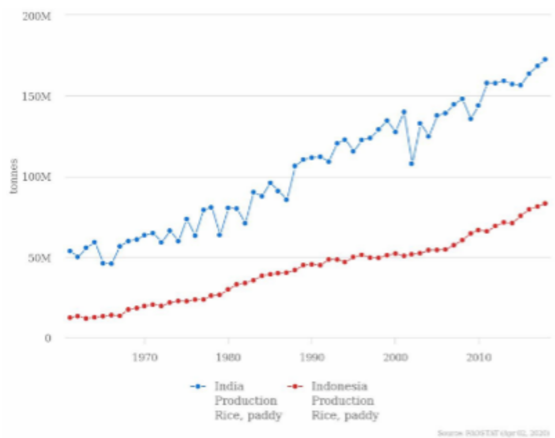


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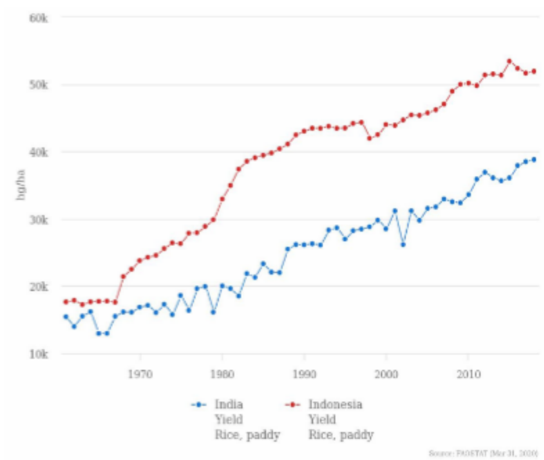
Figure 15: the comparison of rice yield in India and Indonesia



In figure-14 , it can be seen that India has a significantly higher rice production than Indonesia. In 2018, India's rice, paddy production stood at 172580000 tonnes while Indonesia's rice production stood at a much lower quantity of 83037000 tonnes. This shows the huge difference between the production of the countries in terms of quantity.In figure 15, it can be seen that Indonesia's crop yield of rice is much higher than that of India. In 2018, India's crop yield of rice stood much lower at 38782hg/ha while Indonesia's yield stood much higher 63123hg/ha..While India is able to successfully enjoy a larger share of world production in rice by the virtue of its higher area of land under rice production. In 2018, India's harvested area was tremendously higher than that of Indonesia , with 44,500,000 ha while Indonesia has a much lower area under cultivation at 1861313 ha.This points towards the large disparity in the productivity levels of rice in India and Indonesia. From figure 15, it can be seen that Indonesia's productivity is consistently under 1995 , but gains momentum after that and surpasses India in terms of productivity due to appropriate policy interventions.

In 1995 , the agricultural research institutes and other government institutions like State-owned enterprise PT PertaniPerseroSeed control and certification services agency , Rice research agency under the supervisions by MOA and Ministry of State-Owned Enterprises partnered with the farmer groups of Indonesia.Government introduced a contract farming system with the provision of subsidized inputs , technical assistance that ensured a greater price stability and secure market. Under the project, the public funding was 20% that covered the seed inputs while 80% of the cost was covered by the private partners. This provided the farmers an access to high- quality inputs , business management skills developed, access to formal credit facilities and helped in achieving national food security programme . Farmers were assured with the quality ,quantity and continued seed production. It also ensured improved logistics and storage of the yield. The government could successfully meet the requirements of end-customers through appropriate seed varieties. This led a huge increase in the productivity levels of rice and substantially led to an increase in net income to US$4 600/ ha per season – much higher than GNP per capita of US$3 000. Contract farming allows the timely delivery of inputs through credit and technical assistance from different institutions that helps to boost the productivity. It reduces the risk of farmers due to specification of prices in contracts. It provides access to efficient distribution channels, storage capacities and competent marketing to markets that could not have been accessed by small farmers. This oversight and expertise could essentially lead to a greater productivity. However , the downside to this system could be corruption and misallocation of resources on the part of the contractor. The sophistication and capitalisation of agriculture might eliminate disguised unemployment leading to loss of livelihoods and incompatibilities with the farmers cropping regime. It might also lead to the disruption of an existing farming system. The farmers should be responsive to the advancements in cultivation and establish agreements on quality standards. It could lead to an over dependence on credit and might increase the rural indebtedness. However , in the large presence of small and marginal farmers a sharing of risk, assured access to market and credit facilities , technical assistance , efficient crop management practices and quality maintenance would certainly increase the agricultural productivity.

(B) <u>EGYPT</u>

Figure 16: the comparison of maize yield in India and Indonesia

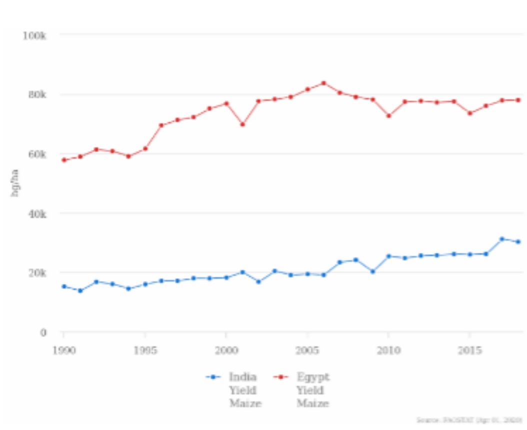
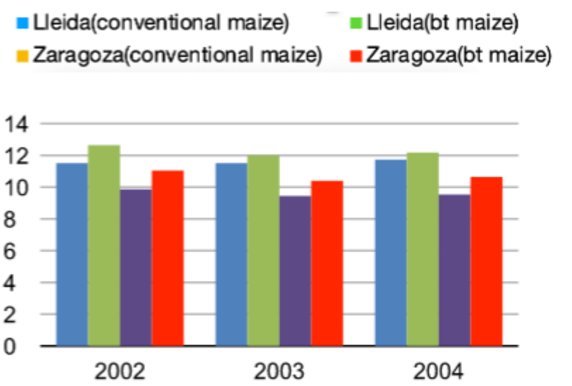


Figure 17: the comparison of yield from conventional maize and bt maize



Source:Gomez-Barbero, M., Berbel, J., & Rodriguez-Cerezo, E. (2008). Bt corn in Spain—the performance of the EU's first GM crop. Nature Biotechnology,

The graph (figure-16) shows that Egypt has a significantly higher productivity of maize than India. In 2018, the maize yield of India was 30239hg/ha while Egypt's productivity stood at a much higher position with 78010hg/ha. It can be seen that Egypt has consistently a higher productivity of maize than India. From the year 2000, maize productivity increases and it doesn't fall to below this value , experiencing a constant increase with mild instabilities.

Since December 2010, genetically modified crops have been planted without restrictions in ten different Egyptian provinces, including one thousand hectares of genetically modified maize in 2012. In 2008, Egypt became the first North African country to grow genetically modified crops.African countries like Egypt, South Africa are engaging in an innovative approach towards research and development. The research on Bacillus thuringiensis (Bt) maize in Egypt presents a unique approach in agricultural biotechnology (agbiotech) through public-private partnerships (PPPs).

Bt maize varieties were developed and commercialised under the partnership between Agricultural Genetic Engineering Institute (AGERI) of Egypt and Pioneer Hi-Bred Company. The collaboration involved the training of AGERI scientists gaining expertise to develop a local strain of btmaize.The private sector pays the legal costs of patenting the innovation and uses the strain in the world market.The training helped the scientists to study the area of maize transformations while allowing Pioneer Hi-bred to gain access to the patents of the institute.The program was supported by Agricultural Biotechnology Support Program of the USAID(United States Agency for International Development) and MSU(Michigan State University) -USA .AGERI has state of the art bio-containment facilities and a team of trained scientists. It provided access to the local Egyptian market and the middle east market that had a lot of potential in the field of biotechnology. On the other side, Pioneer Hi-Bred provided marketing, legal ,regulatory and technological knowledge , and AGERI was able to benefit from the dynamics of the system through technology exchange and mutual support. The collaboration involved intensive field trial studies in over 36-maize growing areas of Egypt. The results showed that the use of genetically modified maize helped in reducing the pesticide requirements , bolstered the protection against stem borers and increased the yield about 30-40%. In addition, it reduced the cost of inputs by decreasing the usage of pesticides. Egypt has also formed partnerships with other American companies like Monsanto. However in 2014, this partnership faced a stakeholder conflict resulting in a temporary stall on the use of GM crops citing patenting issues and lack of biosafety laws and mechanisms for the supervision of research.

The graph (figure-17) shows that genetically modified bt maize has a higher productivity because of a higher disease resistance. This study was conducted in three provinces of Spain (two showed in graph:Lleida,Zaragoza) for three years to show that bt maize has a considerable better agronomics than conventional wheat in terms of yield. Bt maize has a consistently higher productivity than the conventional maize. This points the importance of the growth of R&D sector of a country.

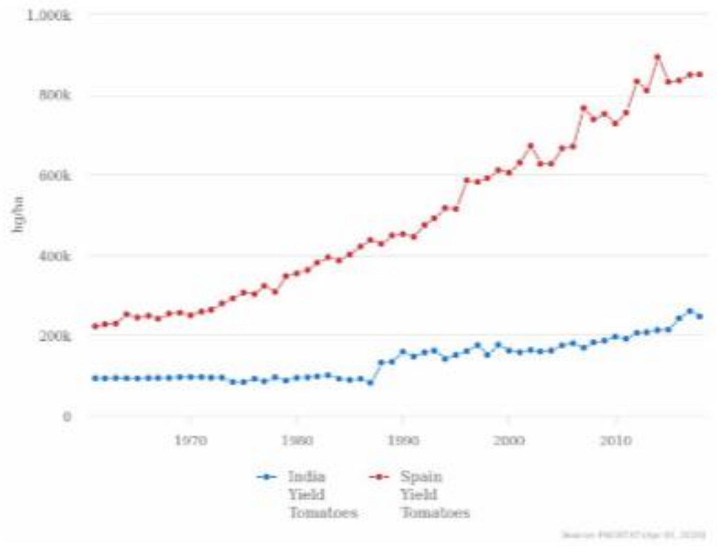
This shows that better technologies could be generated through combing the synergies offered by the public and private sector through strategic partnerships. The example of Egypt shows that PPPs supplement the research done by public research institutions, and better technologies could be generated along with improving adeptness in management of PPP and improving the institutional intellectual property management skills and information database on available technologies in the public sector. This synergetic effect translates intoreturns on investment by combining the private sector's technical expertise, and the public sector's knowledge of local needs and networks. The countries need to move away from the traditional model of mass public funding for public research institutes and form collaborations with companies that are involved in global research on agriculture. For the success of these measures , there should be stronger laws on Intellectual Property, efficient bio-safety regulations that would prevent any halt to the research. There should be transparency of procedures between the stakeholders to prevent information asymmetry. Farmers should be engaged in the process of research, which would raise awareness. The politics of the country must evolve and be proactive in adopting change in approach through a greater support of the private sector. This requires a paradigm shift from the tractional models of public research to a partnership through appropriate incentives aimed at achieving an overall growth in research as well as achieving the mutual objectives . There should be greater alignment of goals between the sectors that would initiate processes for mutual growth ,resulting greater integration and engagement. However the solutions provided by research and development need to be distributed to the farmers efficiently. Farmers in many developing countries lack conventional technologies , so the R&D should be accompanied with proper marketing and commercialisation through government institutions that understand the local markets is the need.

(C) SPAIN

It can be seen that Spain's yield of tomatoes is much higher than that of India. In 2018, the yield of spain stood at 849593hg/ha while India's yield was at a much lower position of 246527hg/ha . This shows the huge divergence in the productivity of Spain and India due to disparities in the state of irrigation.Spain is an example of the use of desalination for agriculture with a long history in this field. In the past, the high cost of desalinating and the energy required have been major constraints on large-scale production of freshwater from brackish waters and seawater. However, desalinated water is becoming more competitive for urban uses because cost of desalinationis declining and the cost of surface of groundwater and surface water increasing due to acute shortages in some regions.From the mid-90s, many farmers and agriculture businessmen decided to install desalination plants in the Southeast of Spain (mainly Mediterranean coastal areas) to solve the problem of available resources.

Table-4: the comparison of the cost and benefits from different sources of irrigation

Figure 18: the comparison of tomato yield in Spain and India



In 2002 a new desalination plant began to solve water problems of this community. A BWRO plant was designed for a total flow of 30,000 cubic metres per day , with the building, intake and other installations having the potential for expansion upto 60,000 cubic metres per day .Given the increasing salinity forecasts and even the possibility of exclusive future use of seawater, the plant was built with components prepared to treat seawater including 1,200 psi pressure vessels, high pressure piping 904L SS and high pressure pumps ready for a Pelton tur- bine coupling, etc. This made it possible to convert current facilities to treat seawater at a reduced cost. Desalination plants have been installed with different raw water qualities (brackish, seawater and wastewater) and technologies (RO, EDR and NF). Desalinated water can be more expensive than water from other origins but this depends on on many factors such as distance to application, energy prices, availability of other resources, etc. As it can be seen in the table-4, the price of water from the BWRO plant is the highest at 0.2284 euro/cubic meter and also requires the highest expenses of 4273 euros. However, if the marginal change in prices and expenses are compared with the benefit, it is the highest in case of desalination plant with 12,268 euro/year.It has higher benefits than both river-interlinking projects and drawing brackish water from wells. remarkable that in some coastal areas where high salinity in wastewater was detected , desalination pants helped to treat secondary water water.

River-interlinking projects could lead to massive displacements, huge investment on infrastructure , geological problems and conflicting goals of different stakeholders.Another problem to evaluate the cost of water, mainly from desalination, is the energy price. In recent years, it has been increasing very fast, and due to this, the main cost in a desalination production, the water costs are continuously increasing (although this occurs also with water from other sources when pumping or other energy consumers are implied).Due to this price volatility of energy sources , a shift to renewable sources could certainly decrease the price .For the success of this procedure for irrigation in agriculture , it requires the presence of efficient micro-irrigation techniques that would increase the efficiency , increase the productivity and lead to an overall decrease in the costs. The implementation of these systems also depends upon the political priorities in a country. Small-scale localised desalination plants can be considered an appropriate intervention in irrigation facility for the use of brackish-water, seawater and secondary waste water. Dams , river water transfer projects etc lead to massive investments in the infrastructure , creating many negative externalities in the process of enhancing irrigation. The costs of desalination could be further reduced through research and development in this field . In the urgent situation of depleting groundwater resources and polluted surface water resources , desalination can provide a huge relief to farmers and can help them to substantially increase agricultural productivity.

Table-4: the comparison of the cost and benefits from different sources of irrigation

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Table 1
Comparison of economic benefits in a farm using water from different sources

Water origin	Superficial (Tajo-Segura Rivers transfer)	Brackish water from wells	Permeate from BWRO plant
Water price (€/m^3)	0.1322	0.054[a]	0.2284 (including payback)
Incomes (fruit sales) (€/year)	15,037	7,519[b]	16,539[c]
Expenses (€/year)	3,885	3,885	4,273
Benefit (€/year)	11,152	3,634	12,268

Note: economic data were supplied by the farmer, participant in the study.
[a]With well in property.
[b]In this case the fruit production is below 50% compared to irrigation with superficial water.
[c]Increased incomes due to the higher production.

VII. WAY FORWARD

India should adopt contract farming that would help in reducing risks and incentivise farmers to continue production. In the last budget , the finance Minster also drew attention to the need for contract farming in India. In the recent past several state governments are resorting to cash transfer schemes to the small and marginal farmers to mitigate distress and to improve productivity. Government of Odisha has propagated the KALIA scheme , Telangana government has rolled out the RythuBandhu Scheme and Government of India implemented the PM-KISAN scheme . While all these initiatives will help in mitigating crisis of the farmers , the long term solution would hinge on higher investment on agricultural R&D , PPP in agriculture and a higher public spending on irrigation. Since land in India is hugely fragmented , with 80% farmers belonging to the category of small and marginal farmers , there is a need to consolidate holdings . The global experience of consolidation has shown that larger land holdings are amenable to mechanisation and higher agricultural productivity. Finally , access to credit and remunerative prices for farm products would be the key to provide incentives to farmers to invest more on agricultural production.

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