Is Punjab Agriculture Sustainable under Business as Usual Mode?

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This paper critically examines the evolution and transition of Punjab agriculture from diversified to unsustainable wheat-paddy crop rotation. The main focus is on the fast depleting water-table due to the paddy-water-energy nexus. It has been found that Punjab agriculture is not going to be sustainable for long under the business as usual mode. As such, there is a dire need for crop-diversification in favour of less water guzzling crops. However, shifting a substantial area currently under paddy would require an appropriate government policy mix similar to that which created an enabling environment for the successful implementation of the Green Revolution. The farmers would also need to be assured of at least the same amount of net per hectare income from alternative crops which they are getting from wheat-paddy crop rotation.

Introduction

Though Punjab has been the food-bowl of the country for more than one and a half century, yet, it acquired renewed predominance with the advent of the Green Revolution (GR) around mid-1960s. The re-organised state of Punjab in 1966 emerged as the splendid success story of the GR and played a remarkable role in providing much needed food security to the country. The GR also gave an upward push to the agricultural and rural economy in particular and state's overall economy in general. On the success of GR, Punjab became the first ranking state economy in the country, both in-terms of its growth rate and per-capita income, and enjoyed this status for well over 25 years. However, from the early 1990s, the growth rate of its Gross State Domestic Product (GSDP) started decelerating which in turn led to its down slide, from 1st rank in terms of per-capita income from around the end of the 20th century. And now the situation is that Punjab has become a laggard state in terms of growth rate as well as per-capita income. Nonetheless, the success story of the green revolution in Punjab did lead to significant socio-cultural and politico-economic changes which, inter alia, have been responsible to putting its agriculture development on capitalist lines.

In terms of GSDP growth rate, Punjab ranked (in the descending order) 13th (among the major states of India) during 1992-97 (8th Five Year Plan period) and 17th during 2007-12 (11th Five Year Plan period). During 2012-17 (12th Five Year Plan), Punjab's rank among all states of India ranged between 20th and 23rd. Unfortunately, the state has not been able to improve its ranking even during recent years. Even the growth rate of agricultural sector has been much below many other states of India over some period of time (Ghuman, 2015). In terms of per capita income, Punjab ranked 11th among the states of India in 2018-19 (GoI, 2021). Such a scenario, combined with lacklustre political will and ill-conceived development priorities, is the root cause of the contemporary economic deceleration, governance failure and agrarian crisis. The exponential rise in Public Debt, rising from 1009 crore in 1980-81 to 2.73 lakh crore in 2021 (accounting for nearly 40% of State's GSDP and debt-service ratio and nearly 40% of state's revenue) is the direct outcome of the above mentioned scenario. All this has impaired state's capacity to govern and play a lead role in the economic development of Punjab. It is in this context that we must first admit that Punjab is beleaguered by the vicious circle of policy paralysis.

There have been a number of factors behind such a disappointing situation. The foremost among them was state's understanding (or miss-understanding) about the colour of GR which started fading around mid-1990s and was reflected in yield stagnation and shrinking net per hectare income. Manifestations of this was seen in increasing number of suicides by the farmers and agricultural labourers since the beginning of the 21st century. As per the official statistics, 16,606 farmers and labourers committed suicide during 2000-16 and about 70% of these were due to indebtedness according to an official study conducted by three state universities, viz., PAU, GNDU and Punjabi University. Based on media reporting, the most moderate estimates suggest that at least 2000 more suicides must have taken place in Punjab during 2017-20. This is a manifestation of agrarian crisis and farmers' distress being experienced for the last three decades (Gill, 2002; Ghuman, 2008). The debt-income ratio of small and medium framers is 1.43 and 1.18, respectively. More than 50 per cent of small farmers' debt is from non-institutional sources (Kaur, 2021).

The implementation of Central Government's three agri-laws of 2020 is bound to augment the agrarian crisis and farmers' distress. The framers call them 'black-laws' and their 'death-warrants'. That is why they have been protesting at the borders of Delhi since 26 November 2020, though the protest against these laws started in June 2020 itself. They have been facing defamation through the government's propaganda machine and 'Godi-media' and due to vagaries of inclement weather. More than 500 farmers participating in the protest have died since November 2020. Despite the unparalleled sufferings by farmers, their distress has never figured in the '*mann ki baat*' of the Hon'ble Prime Minister. It seems that farmers do not figure in PM's 'programme' of '*sabh ka saath sabh ka vikas*' though it is next to impossible to imagine 'vikas' without the vikas of farmers and labourers in particular and that of the rural economy in general.

However, the height of indifference and insensitivity is that the Central Government has adopted a stubborn attitude towards farmers' genuine demands and is rather trying to convince the farmers that these laws are in their best interest even though everybody, including the government, know that these laws are going to benefit the big corporations and their big agri-business at the cost of farmers in particular and common people in general. This seems to be one of the main reasons that the government is neither agreeing to repeal these 'black-laws' nor agreeing to give a legal status to minimum support price (MSP) even for all the 23 crops for which MSP is recommended by the Government of

India's Commission for Agricultural Costs and Prices (CACP). Given the very high proportion of marginal and small farmers - estimated at nearly 60% on the basis of land ownership (Ghuman, 2015b; Ghuman, Kaur and Singh, 2019) - even the Swaminathan MSP may not be a long term solution to their distress and economic crisis (Ghuman, 2015a).There is, thus, an urgent need to formulate and implement a comprehensive policy to address wide spread agrarian crisis and farmers' distress.

The main focus of this paper, however, is not going into diagnosis of economic deceleration of Punjab, agrarian crisis/farmers' distress and the implications of the above mentioned agri-laws, but to critically examine the issue of agricultural sustainability in the backdrop of success story of the GR and the consequent over-exploitation of its precious natural resources, such as ground water. It is in this context that crop diversification has been the subject of debate for the last three and a half decades, though nothing tangible appeared on the ground.

Genesis of the Green Revolution

The story of green revolution (GR) begins in 1943 with the visit of Rockefeller Foundation's team of experts to Mexico for initiating the research programme on promoting food-grains. Norman Borlaug also joined this team after one year (Ghuman, 1983). Later, America's Agricultural Development Council (ADC, established in 1953) and the American Agency for International Development (USAID) started imparting training to a large number of budding agricultural experts and scientists from Asia who later became the forerunners in promoting the GR in their parent countries. In the early 1960s, the Rockefeller Foundation, with the permission of the Government of India, started by introducing some modern agricultural techniques and technology in some selected districts of India under the Intensive Agricultural Development Programme (IADP). Under the programme, rich and big farmers from these selected districts were persuaded to adopt modern techniques of agriculture by giving them new seeds, chemical fertilisers and capital. Later, the Ford Foundation (USA) also played a significant role in promoting the GR in India and other countries. To carry forward the IADP, a number of agricultural universities were established in the decade of 1960s in the countries of Asia, with the help of foreign funding. India also established some agricultural universities, including Punjab Agricultural University, Ludhiana, to promote the green revolution. However, the IADP programme could not show any 'satisfactory' results till the mid-1960s mainly because of the indifferent attitude of governments of host countries. To change such an attitude, the US government in 1966 pulled their strings by attaching three new conditions for countries receiving food aid. They passed new legislation - The Food for Peace Act of 1966 to supplement the earlier Agricultural Trade and Assistance Act, 1954 – both popularly known as the PL-480 or Food for Peace programme. Under these conditions, the recipient country, firstly, would get food-aid only if it shifts its emphasis from industrial development to agricultural development, including enhancing agricultural production and storage capacity. Secondly, the recipient country will need to make all efforts to control its population; and thirdly, governments of such countries would have to open their economies to American capital. Clearly, the politics of western capitalist forces were working hard not only to push GR into Third World countries but also carry forward their political agenda of curbing the expansion of the communist revolution (Husain, 1968; Harry, 1972).

Significantly, the above conditions came into operation during 1965-66, at a time when India was facing a severe drought and food shortages. Perhaps feeling beleaguered by the economic and food crisis, government of India accepted the conditions attached to PL-480 and opened the doors for American capital and the green revolution. The GR, thus, was not confined only to increasing food production. Severe international pressures and country's weak and vulnerable socio-economic conditions were also responsible for the entry of American capital, along with the GR, into India. The implementation of the GR, in turn, transitioned the traditional mode of production into a capitalist mode of production (Rudra, et al, 1969; Patnaik, 1971; Chattopadhyay, 1972; Thorner, 1969; Sau, 1969; Bhalla, 1977; Gill and Ghuman, 2001). The rest is history.

Green Revolution and Sustainability of Punjab Agriculture

With just 1.53 per cent of India's geographical area of the country, Punjab contributed 73 per cent wheat and 45.3 per cent rice to the central pool (buffer stock) in 1980-81. Although the respective share declined to 35.46 per cent and 25.53 per cent by 2018-19, quite clearly, very high proportion of wheat production and an exorbitantly high proportion of rice production of Punjab is still going to the central pool.

The total production of wheat in Punjab increased from 2.45 million tonne in 1966-67 (the beginning of GR) to 17.83 million tonne in 2017-18, an increase of 7.28 times. The per hectare yield of rice in Punjab increased from 1185 kg in 1966-67 to 3229 kg in 1990-91 and further to 4366 kg in 2017-18, an increase of 3.66 fold over 1966-67. The total production of rice in Punjab increased from 0.34 million tonne in 1966- 67 to 13.38 million tonne in 2017-18, an increase by 39.35 times (GoP, 2018, 2019). The higher yield and higher total production of wheat and rice in Punjab, besides increase in area, came at a very high cost in terms of inputs, such as fertilizers, water and pesticides besides soil-heath deterioration, depleting water-table and environmental degradation. The use of chemical fertilisers per hectare on gross cropped area in Punjab increased from 0.038 nutrients tonnes in 1970-71 to 0.247 nutrients tonnes in 2015-16, an increase by 6.5 times (GoP, 1986a & 2019). This in turn led to increased marginal cost and diminishing marginal returns leading to a falling trend in growth rate of net per hectare income and thereby declining farm income of farm-households (Ghuman, 2001). This, inter alia, has been largely responsible for the ever increasing debt burden on farmers and agri-labourers, mounting agrarian crisis, farmers' distress, and incidence of suicides by farmers and agricultural labourers (Gill, 2002, Kaur, 2021; Singh, & Ghuman, 2016 and

2019; Singh, et al, 2014; Singh, et al, 2017; Chand, R., 1999; Gill, 2015; Singh, Bhangoo and Sharma, 2016).

Land use pattern in Punjab

Both the net sown area (NSA) and gross cropped area (GCA) in Punjab has increased over the period of time. The NSA increased from 4053 (80.56% of the geographical area of 5033 thousand hectares) in 1970-71 to 4250 thousand hectares (84.39% of the reporting area) in 2000-01 but declined to 4118 thousand hectares (81.82% of the reporting area) in 2018-19. The GCA increased from 5678 thousand hectares in 1970-71 to 7839 thousand hectares in 2018-19. The cropping intensity increased from 140 in 1970-71 to 190 in 2018-19. This means 90 percent of the NSA was having two crops in a year. The irrigation intensity increased from 71 percent in 1970-71 to almost 100 percent in 2017-18 (GoP, various years).This means the entire NSA and GCA is under assured irrigation in Punjab. Hardly any other state in India is having such a virtuous situation. The all India average share of NSA in total geographical area (TGA) remained between 42% in 1970-71 and 43% in 2014-15. The GCA's share in TGA of India increased from 50% in 1970-17 to 60% in 2014-15. The proportion of GCA to NSA in India increased from 115% to 140% during the same period (Shah, et al 2021).The all India average irrigation intensity is still hovering around 45 percent. This means nearly 55 percent of the area under crops is not having assured irrigation and agriculture there is either dry or rain-fed.

Emergence of Wheat-Paddy Crop Rotation in Punjab

The wheat-paddy crop rotation in Punjab is the manifestation of GR revolution promoted by creating an enabling environment through institutional and technological factors supported by the policies of central and state governments. The objective was to address the problem of hunger and food-deficiency in the country by developing Punjab as the food-granary of the country. With R&D in high yielding variety seeds of wheat and paddy, assured irrigation, assured and subsidised supply of chemical fertilisers along with public investment and government supported extension services (from lab to field) and farmers' willingness to adopt the new technology, Punjab became the front-runner state in food-grain production and the foremost success story of the GR. As a consequence, India became self-sufficient in food-grains but Punjab had to pay a heavy price in terms of serious depletion of water table and deterioration of soil health, besides doing away with diversified-organic-cropping pattern.

In 1970-71, only 390 thousand hectares (9.62% of NSA) were under paddy. This increased to 3103 thousand hectares (75.35% of NSA) in 2018-19. During a span of 48 years, the area under paddy increased by 7.96 times. Significantly, in the per-independence undivided Punjab, the area under paddy was just 8.7% (230 thousand hectares) of the total area (2644 thousand hectares) under irrigation in 1940. The NSA under wheat increased from 2299 thousand hectares

(56.72% of NSA) in 1970-71 to 3520 thousand hectares (85.48% of NSA) in 2018-19. Over the period of 48 years the area under wheat increased by1.53 times. Significantly, in the pre-independence undivided Punjab, the area under wheat was 55.36% (1545 thousand hectares) of the total area (2791 thousand hectares) under irrigation in 1940-41 (Ghuman and Sharma, 2018). Wheat and paddy together accounted for 84.49 percent of the gross cropped area in 2018-19; up from 47.36 percent in 1970-71. Contrary to this, the area under pulses decreased from 903 thousand hectares (19.09% of GCA) in 1960-61 to 414 thousand hectares (7.29% of GCA) in 1970-71; the first causality of the GR. This area dwindled to 30 thousand hectares (0.38% of GCA) in 2018-19. The area under oil seeds dwindled to 41 thousand hectares (0.52% of GCA) in 2018-19 from 297 thousand hectares (5.23% of the GCA) in 1970-71. The area under cotton declined from 701 thousand hectares (16.62 percent) in 1990-91 to 268 thousand hectares (6.51 percent) in 2018-19. The area under maize also witnessed a significant decline from 555 thousand hectares (13.69 percent) in 1970-71 to 109 thousand hectares (2.65 percent) in 2018-19. Even the area under sugarcane decreased from 128 thousand hectares (3.16 percent) in 1970-71 to 95 thousand hectares in 2018-19 (2.31 percent) as is evident from table 1. Thus, the area under almost all crops witnessed a significant decline over the period of time.

Thus Wheat-Paddy crop combination has marginalised all other crops. Wheat accounted for 99.78 per cent of the total area under Rabi cereals and paddy accounted for 96.30 per cent of the area under Kharif cereals in 2017-18. Wheat and paddy together accounted for 98.13 per cent of the total area under cereals and 97.68 per cent of the total area under food-grains in 2017-18. The above data clearly highlights that paddy was not the main crop in the Kharif cereal in the earlier pre-GR period; it was only after the advent of the GR that paddy became the most important crop, rather the only crop in Kharif season. In fact, the GR drastically changed the cropping pattern in Punjab; from diversified to only wheat-paddy agriculture.

Table 1: Shift in cropping pattern in Punjab: 1960-2016

('000 hectares)

Crops	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2018-19
Paddy	227 (6.0)	390 (9.6)	1183 (28.2)	2015 (47.8)	2612 (61.5)	2826 (68.0)	3103 (75.4)
Wheat	1400 (37.3)	2299 (56.7)	2812 (67.1)	3273 (77.6)	3408 (80.2)	3510 (84.4)	3520 (85.5)
Cotton	447 (11.9)	397 (9.8)	649 (15.5)	701 (16.6)	474 (11.2)	483 (11.6)	268 (6.5)
Sugarcane	133 (3.5)	128 (3.2)	71 (1.7)	101 (2.4)	121 (2.9)	70 (1.7)	95 (2.3)
Maize	327 (8.7)	555 (13.7)	382 (9.1)	188 (4.5)	164 (3.9)	133 (3.2)	109 (2.7)

Total oilseeds	185 (4.9)	297 (7.3)	238 (5.7)	104 (2.5)	86 (2.0)	56 (1.4)	39.7 (1.0)
Total Pulses	903 (24.0)	414 (10.2)	341 (8.1)	143 (3.4)	55 (1.3)	20 (0.5)	10.1 (0.2)
Potatoes	9 (0.3)	17 (0.4)	40 (1.00)	23 (0.6)	64 (1.5)	64 (1.5)	130 (3.2)

Source: Govt. of Punjab, *Statistical Abstracts Punjab* (various issues).
Note: 1. Figures in parentheses indicate percentage share to net sown area.

The water-intensive paddy crop, which was never a natural crop and staple diet of Punjab, became the villain of peace as it led to an ever increasing extraction of ground water with an exponentially increasing number of tube-wells. Over a period of time there developed an ‘agri-water nexus, nay, ‘paddy-water nexus’ as wheat is less water intensive crop. Table 2 below clearly depicts this nexus.

Irrigation Pattern in Punjab

In 1960-61, out of the total irrigated area of 2020 thousand hectares, 1173 thousand hectares (58.07 %) was under canal water and 829 thousand hectares (41.04 %) was under tube-wells and wells. The irrigation intensity was 54 per cent in 1960-61. With the advent of the GR, the area under irrigation increased to 2888 thousand hectares in 1970-71, out of which 1286 thousand hectares (45.47 %) was under canal irrigation and 1591 thousand hectares (56.26 %) was under tube well irrigation. The areas under canal irrigation increased by just 113 thousand hectares while the area under tube wells increased by 762 thousand hectares in one decade. The area under canal irrigation (1660 thousand hectares) reached at its plateau in 1990-91 and thereafter it started declining, both in absolute and relative sense. The additional area under irrigation after 1990-91 was being served by tube-wells and hence share of tube-wells irrigated area registered a continuous increase since 1960s as high yielding variety of seeds (especially paddy) were highly responsive to water. Hence, assured supply of water was not a choice but a necessity. Interestingly, sub-soil water became very handy to the farmers. In 2000-01 the share of tube-well irrigated area increased to 76.45 per cent (3074 thousand hectares) and thereafter its share remained around 71 per cent see Table 2.

Table 2: Net Sown Area under Irrigation in Punjab through Canals and Tube-wells: 1960-2019

(‘000 hectares)

Year	Government Canals	Tube wells & Wells	Total Irrigated Area of the State	Irrigation Intensity
1960-61	1173 (58.07)	829 (41.04)	2020	54
1970-71	1286 (45.47)	1591 (56.26)	2888	71

1980-81	1427 (42.19)	1939 (57.33)	3382	81
1990-91	1660 (43.50)	2233 (58.52)	3816	93
1996-97	1620 (40.15)	2408 (59.68)	4035	95
1997-98	1296 (32.37)	2705 (67.56)	4004	94
2000-01	1002 (24.92)	3074 (76.45)	4021	94
2010-11	1113 (27.35)	2954 (72.58)	4070	98
2011-12	1113 (27.24)	2970 (72.69)	4086	99
2012-13	1113 (27.05)	2982 (72.47)	4115	99
2013-14	1160 (28.01)	2981 (71.99)	4141	99
2014-15	1175 (28.53)	2943 (71.47)	4118	99.9
2015-16	1201(29.03)	2936(70.97)	4137	99.9
2016-17	1152(27.91)	2975(72.09)	4127	99.9
2017-18	1176(28.52)	2918(71.48)	4124	99.9
2018-19	1169(28.68)	2907(71.32)	4076	99.9

Source: Govt. of Punjab, *Statistical Abstracts of Punjab* (various years)
Note: 1. Figures in brackets indicate percentage share; the total may not add up to 100 per cent as there are other sources of irrigation also though very small area is under those.

2. The total irrigated area may exceed the sum total of area under canal and tube well irrigation as the difference is under some other sources (less than half a per cent) of irrigation

It is understandable that more water was required for wheat-paddy crop rotation system but the moot question is why did the absolute area under canal irrigation decline from 1620 thousand hectares in 1990-91 to 1152 thousand hectares in 2016-17? In 2000-01 the canal irrigated area was exceptionally low. Instead of increasing, the area under canal irrigation witnessed a significant decline. This needs a plausible explanation from the government, policy makers and farmers. Table 2 also highlights that besides the area, irrigation intensity also increased from 54 per cent in 1960-61 to 94 per cent in 2000-01, and further to 100 per cent in 2014-15. In other words, almost the entire net sown area in Punjab was under assured irrigation in which the share of tube well irrigation is more than 71 per cent. In June 2015, the Union Government had rolled out a plan to spend Rs.50, 000 crore for the provisioning of irrigation in certain states of India. The availability of sub-soil water and the appropriate soil-texture, unlike in Punjab, will always be a constraint as many parts of India may not have sub-soil water. In certain areas there is near absence of sub-soil water. This also implies that movement of rice out of Punjab is also movement of water!

Increasing Dependence on Ground Water and Nexus between Tube-wells and Paddy

To meet the increasing demand for irrigation, especially for rapidly increasing the area under paddy (highly water intensive crop), dependence on ground water increased in a big way. In the initial years of the GR era, ground water became very handy and the most reliable source of irrigation (Dhawan, 1975 and 1982; Singh and Joshi, 1989). The technological shift and policy directions revolving around food security of the country led to wide development and usage of ground water in Punjab (Sarkar, 2011). As a matter of fact, ground water played a significant role to make Punjab a success story of the GR. It reduced the risk of drought's adverse impact on yield as high yielding varieties of wheat and paddy are highly responsive to assured irrigation. The higher yield led to private installation of tube-wells as higher yield outweighed the initial increase in cost. Public support and global agri-business had also encouraged the installation of private tube wells for irrigation (Ghuman, 1983; Dhawan, 1982; Ghuman and Rajeev, 2018).

This, in turn, led to a mind-boggling increase in the number of tube-wells (Table 3). Their number increased from 1.92 lakh in 1970-71 to 6 lakh in 1980-81, 8 lakh in 1990-91, 13.82 lakh in 2010-11 and further to 14.76 lakh in 2017-18. Thus the number of tube-wells increased by more than 7 times - much higher than the increase in net sown area (NSA) and the gross cropped area (GCA). The net area sown (NAS) increased from 40.53 lakh hectares in 1970-71 to 41.18 lakh hectares in 2018-19 - an increase of only 1.02 times or 1.60 per cent. The gross cropped area (GCA) on the other hand increased from 56.78 lakh hectares in 1970-71 to 78.39 lakh hectares in 2018-19 - an increase of 21.61 lakh hectares or 38.06 per cent. Evidently, the number of tube wells registered a highly disproportionate rise as compared to the rise in net area sown and gross cropped area.

The many-fold increase in the number of tube-wells seems to have very high correlation with the rising area under paddy. The number of tube-wells increased by 668.75 percent while the area under paddy increased by 764.34 percent during the span of 49 years. Interestingly, during the 1970s decade, the number of tube wells and the area under paddy registered a very close increase to each other in percentage terms. The latter decades displayed a similar relationship between the number of tube-wells and the area under paddy.

Table 3: Tube-wells and Paddy Production

Year	Tube-wells	% Increase	Area under paddy ('000 hectares)	% Increase
1970-71	1.92	--	359	--
1980-81	6.00	212.50	1178	228.13
1990-91	8.00	33.33	2024	71.82
2010-11	13.82	72.75	2831	39.87
2018-19	14.76	6.80	3103	9.61
2018-19 over 1970-71	12.84	668.75	2744	764.34

Source: Government of Punjab, *Statistical Abstract of Punjab* (various years); and Ghuman and Sharma, 2016.

Water Productivity of Rice

Water-rice productivity is the lowest in Punjab in comparison to all the major rice producing states of India. The all India average consumption of water per kg of rice is 3875 litres, while it is 5337 litres in Punjab and 2605 litres in West Bengal (Table 4).

Table 4: Water Productivity of Rice in Major Rice Producing States in India

State	Water productivity of Rice, TE 2013-14	
	Water Litres/kg of rice required	Efficiency Gap (%)*
West Bengal	2605	0.0
Karnataka	2797	6.8
Assam	2783	6.4
Andhra Pradesh	3145	17.2
Bihar	3178	18.0
Tamil Nadu	3345	22.1
Chhattisgarh	4197	37.9
Odisha	4219	38.2
Haryana	4232	38.4
Uttar Pradesh	4564	42.9
Punjab	5337	51.2
All India	3875	32.8

Source: *Price Policy for Kharif Crops*, CACP, Ministry of Agriculture, Government of India, 2015.
Note: *Efficiency Gap = (1-water productivity of the state/highest water productivity)*(100).

On basis of discussion above on water-rice productivity, it has been worked out that Punjab has consumed a lot of its ground water in producing and contributing rice to the central pool of the country as is clearly evident from calculations for selected years shown in Table 5. During the triennium ending (TE) 1980-81, rice production in Punjab consumed 16643 billion litres of water out of which the component of contribution of rice to the central pool accounts for 13449 billion litres (81%). The corresponding figures for the TE 2000-01 were 45916 billion litres, of which about 37039 billion litres (80.7%) went to the central pool. In 2017-18, the water consumption in the total producing of rice increased to 71928 billion litres of which 63626 billion litres (88.5%) went to the central pool. The water consumption on total rice production in Punjab increased 3.55 times during 1980-81 and 2017-18. During the same period, the contribution of water to the central pool (in the form of rice) increased by 3.22 fold. Clearly, most of the rice production of Punjab went to the central pool. Consequently, between 73 and 81 per cent of the water consumption in rice produce was virtually meant for the central pool. This clearly presents the case of 'virtual water export' from Punjab to the rest of India – see Table 5 below.

Table 5: Water consumption in Rice Production in Punjab and the Virtual Water Export from Punjab

Year	Production (million tonnes (MT) and % increase)		Water Consumption in total Rice Production		Water Consumption by Rice contributed to central pool		
	MT	% Increase	Billion Litres	% Increase	Billion Litres	% Increase	% Share
1980-81	3.12	-	16,643	-	13,449	-	80.8
1990-91	6.05	93.91	32,301	94.08	25,724	91.27	79.6
2000-01	8.60	42.14	45,916	42.15	37,039	43.98	80.7
2013-14	11.06	28.60	59,046	28.59	43,262	16.80	73.3
2017-18	13.38	20.97	71,928	21.81	63,626	47.07	88.5

Source: Ghuman, R.S and Rajeev Sharma, 2018.

Alarm Bells of Depleting Water Table

Table 6 shows that an ever increasing over-draft of ground water led to higher and higher number of over-exploited blocks over a period of time. The number of over-exploited blocks increased from 53 (44.92 per cent) in 1984 to 105 (76.09 per cent) in 2013 and further to 109 (78.99) per cent in 2017. The number of safe/white blocks decreased from 36 in 1984 to 22 in 2017. In 13 out of total 22 two districts, 100 per cent blocks are in the overdraft category. In another two districts, 80 per cent blocks fall in this category.

Table 6: Over-exploited blocks in Punjab

Category	1984	1999	2004	2009	2011	2013	2017
Dark/Over exploited	53 (44.9)	73 (52.9)	103 (75.2)	110 (79.7)	110 (79.7)	105 (76.1)	109 (79.0)
Dark/ Critical	7	9	5	3	4	4	2
Grey/ Semi Critical	22	18	4	2	2	3	5
White/Safe	36	36	25	23	22	26	22
TOTAL	118 (30.5)	118 (27.5)	137 (18.3)	138 (16.7)	138 (16.7)	138 (18.8)	138 (15.9)

Source: CGWB. (2019). *Report on Dynamic Ground Water Resources of India, 2017*, Central Ground Water Board, Ministry of Water Resources, Government of India, Faridabad. Computations made by the author.
Note: Figures in brackets indicate percentage share in total blocks.

The net annual ground water availability for irrigation development was 2.44 million acre feet (MAF) in 1984 which decreased to 0.22 MAF in 1999. It dwindled to minus 8.01 MAF in 2004 and further to minus 11.81 in 2017 (see Table 10). Such a dark situation was reached due to over exploitation of ground water (see Table 7). The aggregate gross ground water draft in Punjab increased from 149 per cent in 2013 to 166 per cent in 2017. The number of overexploited districts increased from 11in 2004 to 17 in 2017 and the number of districts with more than 200% overexploitation increased from 02 to 07 (CGWB, 2019).

The deteriorating *quality* of ground water is also a serious challenge in Punjab as there are a number of quality hazards tagged with ground water such as Arsenic, Fluoride and Salinity in many regions of the state (Kulkarni, H. & Shah, M., 2013). Increasing water pollution due to urbanization, industrialisation and increased use of fertilisers and pesticides is causing water quality deterioration of surface and ground water resources (CGWB, 2018). The contamination of groundwater at shallow depth is mainly being caused by surface water pollution. According to the CGWB (2019) nearly 15-25 per cent of the groundwater is saline/alkaline and not fit for irrigation use and generally found in isolated patches in south and south-western parts of the state. The problem is even more severe in terms of salinity in the districts of Muktsar, Mansa and Bathinda. Poor groundwater quality is another serious challenge in Punjab as 14.72 per cent (848628 hectares) of state's area was having poor groundwater quality as on 13 March 2017 (CGWB. 2019)

Table 7: Net Annual Ground Water Availability for Irrigation Development

Year	Ham	Decline		MAF
		Ham	%	
1984	301929	-	-	2.44
1989	67914	234015	77.51	0.55
1992	103177	35263*	51.92*	0.84
1999	27101	76076	73.73	0.22
2004	(-)988926	1016027	3749.04	(-)8.01
2009	(-)1457475	468549	47.38	(-)11.81
2011	(-)1483189	25714*	1.76	(-)12.02
2013	(-)1162414	320775	21.63*	(-)9.42
2017	(-)1457621	295207	25.40	(-)11.81

Source: CGWB. (2019). *Report on Dynamic Ground Water Resources of India, 2017*, Central Ground Water Board, Ministry of Water Resources, Government of India, Faridabad.
HAM = hectare per mitres; MAF = million acre feet

As per the latest report (2019) of the Central Ground Water Board, in 18 of all the 22 districts of Punjab the draft was more than 100 per cent in 2017. Among them, 7 districts are such in which the draft is in the range of 208 and 260 per cent. In another 4 districts the draft is between 151 and 200 per cent and in 7 districts the draft varies between 101 and 150 per cent. Out of the remaining 4 districts, in two the draft is 98 and 99 per cent and in another two it is 74 per cent and 76 per cent, respectively. Thus, in 18 districts there is serious over-drafting of ground water while in another two districts the situation is critical and still in another two it is semi-critical. Thus almost the entire Punjab is in for serious water scarcity as there is no safe zone as far as water extraction is concerned. The computations done by this author shows that during 1996-2016, out of 17 districts, 12 have witnessed a significant decline in water table ranging from 3.55 metres to 22.05 meters. These are predominantly paddy growing districts. Paradoxically, the annual average rainfall decreased from 673 millimetres (mm) during 1975-85 to 438 mm during 2009-13. In 2014 it was 385 mm and in 2016 it was 427mm and 598 mm in 2018. Thus, the average rainfall in Punjab has witnessed a significant decline but there has been wide variation spatially and temporally (Ghuman and Sharma, 2018).

It is quite worrisome that out of the total geographical area of Punjab of 5033 thousand hectares, the area where ground water table is more than 10 metre deep has been continuously increasing. It was 7, 49,600 Ha (14.9%) in June 1989, 10, 23,400 Ha (20%) in June 1992, 14,15,100 Ha (28%) in June 1997, and 22,07,300 Ha (44%) in June 2002. It further increased to 30,41,800 Ha (61%) in June 2008, 32,36,100 Ha (64%) in June 2010, 33,10,400 Ha (65%) in June 2012 and 33, 177,00 Ha (65%) in June 2016. There is 343 per cent increase in the area having ground water table of 10 metre or more during a span of 27 years.

Energy Consumption in Agriculture in Punjab

Most of the farmers had to deepen their tube-wells between 6 to 8 times during 1975-2005. The average additional depth of tube wells was around 60 feet during that period (Ghuman and Romana, 2008). In such a situation, 65 to 70 per cent of the Punjab farmers may not be in a position to afford the additional cost of deepening the bore and cost of installing the submersible motors. The falling water table also necessitates the installation of motors with higher and higher horse power, in turn, resulting in additional cost and higher energy consumption.

Such a fast depletion in water table, along with degrading quality of water, will have a negative impact on the environmental. That, in turn, would have negative impact on total factor productivity in agriculture. The negative contribution of environmental factors - of which water depletion and degradation are the prominent - to total factor productivity in rice increased from 1.42 per cent during 1982-90 to 5.04 per cent during 1990-97. In the case of wheat the corresponding figures were -0.74 per cent and -1.58 per cent, respectively (Singh and Hossain, 2002).

Due to increasing dependence on ground water irrigation, depleting water table and frequent deepening of tube-wells, (Romana, 2006; Ghuman and Sharma, 2018) the demand for energy in agriculture has increased many folds. The electricity consumption in agriculture increased from 463 million KWH in 1970-71 to 1850 million KWH in 1980-81, to 5104 million KWH in 1990-91, to 5534 million KWH in 2000-01 and to 12484 million KWH in 2017-18. Over 1970-71, the electricity consumption in 2017-18 witnessed an increase of nearly 27 times. As compared to this, the gross cropped area increased only by 1.38 times while the irrigation intensity increased by just by 29 percentage points during the same period. The percentage increase of electricity in 2018-19 over 1984-85 for the then total 12 districts varied between 59 per cent (Amritsar) to 573 per cent (Sangrur). Bathinda registered an exceptionally higher increase (1133%) during this period. Significantly, the higher increase has been witnessed, inter alia, in those districts which are predominantly rice growing (GoP, 2019).

The depletion of the water table and frequent deepening of tube-wells led to increase in demand for submersible electric motors, from 619 thousands in 2009 to 979 thousands in 2017. And now more than 90 per cent are submersible motors in Punjab. This led to an ever increasing number of high BHP electric motors for ground water extraction - see Table 8. The number of motors with more than 10 BHP increased from 273719 (24% of the total) in 2010 to 458086 (34% of the total) in 2020. Given the rate of water table depletion, the share of motors with BHP higher than 10 is likely to go beyond 70%. This would lead to higher demand for energy and need for much higher financial resources. In 2002, an expert committee estimated that during the next 15 to 20 years, huge investment of Rs. 30000 million would be required for deepening the existing tube-wells if the decline of ground water was not arrested (GoP, 2002).

Table 8: Transition from Lower to Higher Horse Power of Electric Motors in Agriculture in Punjab

BHP	2010	2020	% Change
Up to 3	101275	143296	41.49
5	306935	345768	12.65
7.5 + 10	454703	415669	-8.58
12.5+15	191301	330942	72.99
17.5+20	78928	123145	56.02
Above 20	3490	3999	14.58
Total	1136632	1362819	19.90

Source: Punjab State Power Corporation Limited, Head Office, Patiala, Punjab.

Due to increasing demand for energy the amount of power subsidy to the agriculture sector (because of provision of free electric power) increased from Rs. 900 crore in 2002-03 to Rs. 5197 crore in 2016-17 and is estimated to reach 6728 crore in 2021-22.

Crop Diversification is a Must but How?

It is evident from the foregoing discussion that over a period of time there developed a water-energy-paddy nexus in Punjab which is going to put a great challenge to the sustainability of business as usual agriculture. Paddy's consumptive use of water is much higher than other seasonal crops (Vaidyanathan and Sivasubramaniyan, 2004. As regards evapo-transpiration (ET), it is quite high in paddy (650 mm), followed by cotton (600 mm), maize (480 mm), wheat (380 mm). The ET in the case of sugarcane is 1350 mm, but it is a whole year crop. Large scale cultivation of paddy-wheat rotation has been a major factor of over-exploitation of ground water (Arora, et al, 2008; Gill and Nehra, 2018). Farmers in Haryana -where electricity for farm sector is highly subsidised - are also indulging into excessive irrigation of paddy crop. Some other studies (Kaur, Vatta and Sidhu, 2015; Ghuman, 2017) have also come up with similar findings for Punjab, where electricity for farm sector is free. The judicious and optimum use of water is also the need of the hour (Sidhu, Vatta and Lall, 2011).

Inefficient and sub-optimal use of ground water is bound to put a serious question mark on the economic viability of wheat-paddy crop rotation and would augment the farmers' distress and agrarian crisis. However, despite some efforts at developing alternative crops, there is hardly anything on the ground. The economic viability of alternative crops is a major hurdle in the way of crop diversification. There is absence of an enabling environment for the promotion of alternative crops such as maize, cotton, basmati rice (fine quality rice), pulses, oil seeds, vegetables and fruits. Crop diversification has been the subject of debate for the last about 35 years but nothing tangible came out in terms of effective policies and outcomes. The two committees (GoP, 1986 and 2002), constituted by the government of Punjab for restructuring and diversifying agriculture, made a significant recommendation for shifting substantial area (20 per cent) from under paddy but it did not cut any ice. The Draft Agricultural Policy (2013) and (2019), prepared by the Punjab State Farmers' Commission, also recommended crop diversification by shifting a substantial area from under paddy but so far the state neither has agricultural policy nor water policy. Paradoxically, even the Punjab Water Development and Regulatory Authority, constituted in 2020, and has not included irrigation under its purview.

On the other hand, even though the country still has a high level of dependence on Punjab's food grains, and as a consequence Punjab is facing serious water table depletion, the central government continues to advise Punjab to go in for crop diversification and reduce area under paddy - but without any policy prescription and financial aid.

In needs to be understand that paddy was promoted by the enabling environment created by the policy set of high yielding variety seeds and open-ended procurement at the MSP by the government agencies. A number of critical questions come to mind. The most crucial question is, given that the ground water situation is so precarious in Punjab, why is the area under paddy still so high? Why, despite the long felt need for crop diversification, is it not taking place, especially when a number of less water consuming and high value crops (such as maize, pulses, oilseeds, vegetables and fruits, etc.) are easily available? Why are the farmers not cultivating these alternative crops? Though these questions need a larger debate, the continuing policy support and open-ended assured public procurement at minimum support price ever since mid-1960s and access to free power for agriculture from 1997 onwards may be the most prominent reasons for such a scenario.

The phasing out of paddy or shifting a substantial area from under paddy would require a policy mix and incentives to farmers, both by the central and state governments. The farmers would have to be assured for at least the same amount of net income from alternative crops which they are getting from wheat-paddy crop rotation. This requires an enabling environment for developing and growing such crops which could become an economically viable alternative to paddy. If the central government is genuinely interested in crop diversification then it should be done by a compatible policy intervention. The farmers would certainly go in for crop diversification if they are assured, at least the same amount of per hectare net income, from alternative crops. That, inter alia, would require R&D in alternative crops, procurement of those crops at the MSP and compensation for the difference in price, if any. Both the centre and state government would have to join hands for any effective crop diversification policy.

Clearly, under the business as usual model, i.e., the monoculture of wheat-paddy crop rotation, Punjab agriculture is not going to be sustainable for long because the water table is going down at a very fast pace. Demand for water is going to continue to increase and to address the problem there will be no alternative but to go in for a combination of crop diversification and intelligent water saving technologies. Such a measure would reduce water demand in agriculture, from 2.85 million hectare metres under business as usual, to 2.47 million hectare metres by 2050. The estimated electricity demand by the agriculture sector will also be reduced - it is expected to increase to 24-39 billion kwh from 11-13 billion kwh under the business as usual model (Vatta and Taneja, 2018).

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