TREND AND CONSEQUENCES OF RICE WHEAT MONO-CROPPING IN HARYANA, INDIA

Virender* and Dr Poonam Shah**

*Junior Research Fellow and **Assistant Professor, Geography Department,

S.B.S. Government P.G. College, Rudrapur (Udham Singh Nagar) Uttarakhand

Affiliated to Kumaun University, Nainital

Abstract. India's population is expected to reach 1.64 billion by 2050 and to surpass China as the world's most populous country by 2027 (UN report). It is necessary to increase the production of nutritious food to feed the world's ever-increasing population. Haryana is an agrarian state that is a major contributor to the nation's food supply. It will assist India in meeting the Sustainable Development Goal 2 (SDG 2) by 2030, which includes the elimination of hunger, the achievement of food security and improved nutrition and the promotion of environmentally sustainable agriculture. Crop specialisation has reached a significant level as a result of the availability of high-yielding seeds, chemical fertilisers, well-connected irrigation facilities, improved road networks and the opening of new markets. Haryana's agriculture has seen a clear paradigm shift from diversified cropping patterns to mono-cropping patterns. In recent years, the state has been confronted with the consequences of specialised cropping patterns based on rice and wheat production. Numerous environmental, agricultural and livelihood-related consequences resulted from the extensive monocropping pattern characterised by rice and wheat production. This paper examines the trend analysis of the current cropping pattern from 1966-67 to 2015-16, as well as a more in-depth investigation into the negative consequences of this monocropping strategy.

Keywords. *Rice wheat cropping pattern, consequences, monocropping, Haryana*

Introduction. Until the 1960s, the country's main challenge was food insecurity because India was not self-sufficient in terms of foodgrain production during that time. Famine was common and millions of people died as a result of famine. Under the direction of MS Swaminathan, India began the ***green revolution*** program to achieve self-sufficiency in terms of foodgrain production and food security. Progressive farmers of Haryana, Punjab and western Uttar Pradesh were the first to implement the initiative because of their unique geographical location and well-equipped irrigation infrastructure. Under this program significantly high growth of food grain production was achieved with the help of increasing total agricultural land, increasing net shown area by introducing multiple cropping, introducing high yielding varieties (HYVs) seeds, irrigation facilities, agricultural machines, Chemical inputs (fertilisers, pesticides and herbicides), etc. The government invested a huge amount in major infrastructural projects like roads, railways, markets and mandies, agricultural universities, irrigation facilities, etc. Farmers were encouraged to grow a lot of rice and wheat because of things like guaranteed Minimum Support Price (MSP), subsidised electricity for water lifting, subsidised fertiliser, government awareness programmes and a lot more. Magnificent growth in the production of rice and wheat crop has helped India to become self-sufficient in food production and also a major exporter of foodgrain. The idea behind the green revolution was to increase the foodgrain production and feed the millions of hungry stomachs however, its environmental impacts were not been taken into account. This monocropping practice of rice and wheat put a negative impact on agriculture, environment, human health and livelihood, water availability and its quality, livelihood, etc.

Methodology. The present study is a descriptive review analysis based on secondary data extracted from the Agricultural Statistical Abstract of Haryana (various years), the district statistical office, an economic survey, government publications and reports. To look at the effects of rice-wheat monocropping in Haryana, many research papers on the same subject have been looked at and used.

Data Source. On 01 Nov 1966, during the time of the green revolution, Haryana was constituted and became the 17th state of India. The state lies in subtropical and semi-arid type climatic conditions with an average rainfall of 650 mm. 86 % of its land is arable, out of that 96 % is under cultivation. Irrigation is provided by tube wells and a vast network of canals around 75% of the area. Wheat, rice, barley, cotton, oilseeds, maize, bajra, pulses, jowar and sugarcane are the state's primary crops. The state is known as the "Bread Basket of India". Despite occupying less than 1.4 percent of the geographical area, Haryana is the sixth-largest producer of foodgrain, producing 16.38 million tonnes on a 4.47 million hectare area(Haryana, 2022). Haryana is the country's fourth-largest wheat producer, accounting for approximately 12% of total wheat production. In terms of total rice production, the state ranks tenth (Agriculture, 2016).

Objectives. The major objectives of the study are as follows:

- To analyse the trend of cropping pattern in Haryana from 1966-67 to 2015-16.
- To analyse the crop specialisation practice of rice and wheat in Haryana.
- To review the negative consequences of the monocropping pattern in Haryana.

Crop Production. Haryana is self-sufficient in food production and is the second-largest contributor to India's central pool of food grains. There is a surge of 947% in the overall production of paddy and wheat in the state and an overall decline of 32% has been recorded in the production of maize, barley, bajra and pulses between 1966-67 and 2015-16(Kumar, 2017).

Table- 1: Total Production (in 1000 tonnes)

Year	Rice	Wheat	Barley	Cotton	Oilseeds	Maize	Bajra	Pulses
1966-67	223	1059	239	287	92	86	373	563
1970-71	460	2342	124	373	98.8	130	826	832
1975-76	625	2428	221	465	79.4	171	608	952
1980-81	1259	3490	181	643	187.5	81	474	502.5
1985-86	1633	5260	160	745	287.8	64	315	686.6
1990-91	1834	6436	107	1155	638	49	526	541.7
1995-96	1847	7291	100	1284	783.1	48	409	450.7
2000-01	2695	9669	118	1383	562.8	34	656	99.8
2005-06	3194	8853	79	1502	822.1	36	706	111.8
2006-07	3375	10059	115	1805	821.2	30	1021	136
2007-08	3606	10232	120	1882	617.2	37	1156	101.1
2008-09	3299	11360	185	1862	911.5	25.2	1087	177.6
2009-10	3628	10488	137	1918	862	26	930	97.3
2010-11	3465	11578	130	1747	964.9	19	1183	153.1
2011-12	3757	13119	149	2621	545.8	30	1175	107
2012-13	3941	11117	167	2378	970	26	791	285.6
2013-14	4041	11800	151	2025	899.1	24	829	90.9
2014-15	4007	10707	105	1943	739.5	18	670	54.5
2015-16	4145	11352	99	NA	NA	17	652	40.1

(Source: Statistical Abstract of Haryana of various years)

Figure - 1

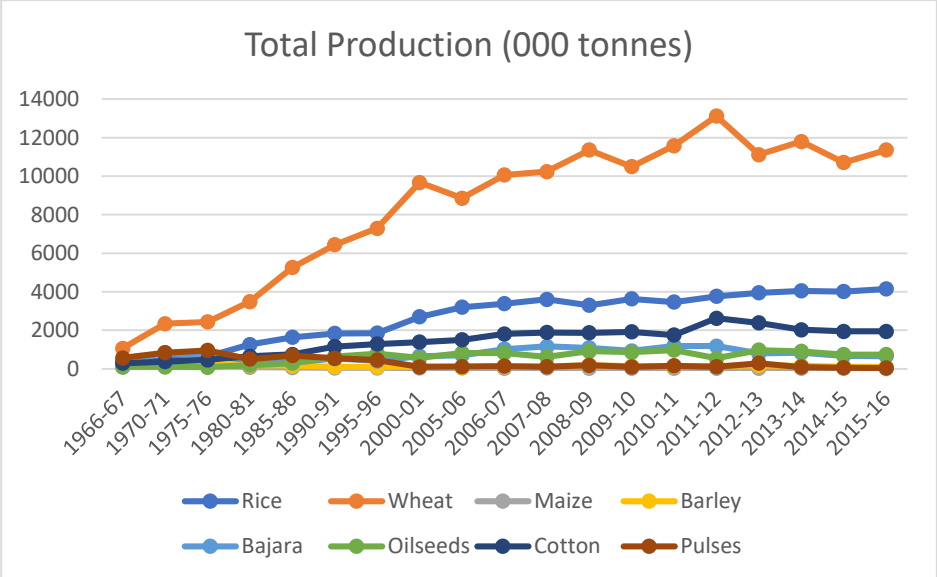


Table 1 and **figure 1** elaborate that paddy production has increased nearly 19 times between 1966-67 (223 thousand tonnes) and 2015-16 (4145 thousand tonnes). During the same period, the total area planted for rice has increased sevenfold from 192 thousand hectares to 1354 thousand hectares. Similarly, wheat production increased 11 times in the same period, while the total cropped area increased 3.5 times. (Various years of Haryana Statistical Abstract). Before the green revolution, the total cropped area was well-diversified, including barley, bajra, maize, pulses, cotton, oilseeds, rice and wheat. However, over the last 50 years, the share of rice and wheat has increased significantly and as a result, the total cropped area of pulses, barley, bajra and maize has decreased dramatically(Aggarwal & Moudgil, 2015).

Cropping Pattern in Haryana. Haryana is the state which achieved a tremendous 5.33% compound rate of growth in food grain production as compared to the national average of 2.77%, during the initial phase of the green revolution (1966-1980). Paddy and wheat registered a huge growth of 12.47% and 8.93% respectively; whereas during the same period pulses and oilseed recorded a fall of 5.12% and 0.64% respectively(Kumar, 2017).

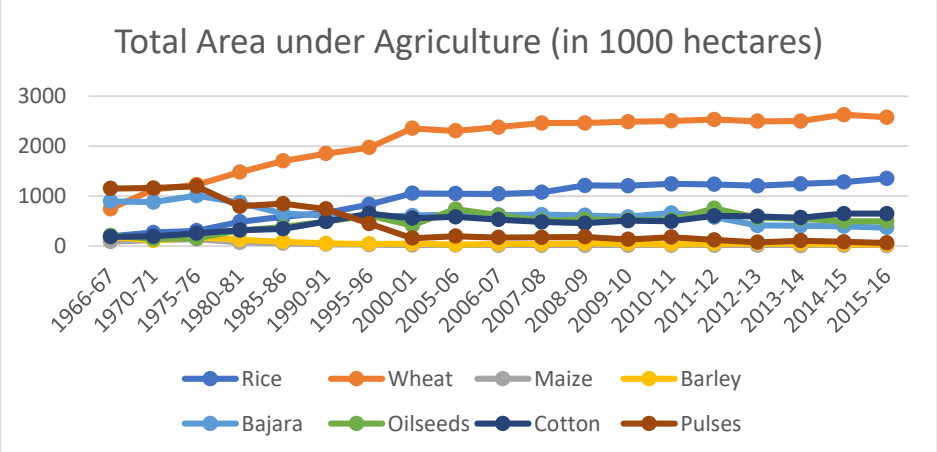
Table-2: Total Area under Agriculture (in 1000 hectares)

Year	Rice	Wheat	Barley	Cotton	Oilseeds	Maize	Bajra	Pulses
1966-67	192	743	182	183	212	87	893	1150
1970-71	269.2	1129.3	108.6	193.4	142.6	114.4	879.6	1158.9
1975-76	303.5	1226	177.1	255	153.5	138.7	1005.6	1193.9
1980-81	483.9	1479	124.5	316.2	311.2	71.3	870.3	794.8
1985-86	584	1701.3	87.7	344.1	380.1	54.9	649.5	846.3
1990-91	661.2	1850.1	50.5	490.6	488.5	34.8	608.6	742
1995-96	830	1972.1	40.6	651.8	611.0	26	575.2	449.8
2000-01	1054	2354.8	44.1	555.4	414	15.4	608.3	157
2005-06	1046.6	2302.7	28.2	583.8	735.8	17.5	631	195.3
2006-07	1042	2377.1	37.7	527.7	616.2	13.4	619	169.3
2007-08	1072.5	2460.7	39.5	482.5	511.3	13.8	628	172
2008-09	1211.2	2461.4	53	456.1	527.6	11.8	612.9	184.1
2009-10	1206.4	2487.7	42.1	505.1	523	12.2	583.8	131.6
2010-11	1243.3	2504	37.3	493.3	521	9.6	659.6	175.6
2011-12	1234.1	2531.3	41.2	601.8	754.8	11	576.2	123
2012-13	1206.3	2496.9	47.7	592.6	567.6	9.9	410.7	75.3
2013-14	1244.6	2499.1	38.6	567.8	548.5	8.5	403.6	105.3
2014-15	1277.9	2628.1	35.3	647.2	495.4	8.8	393.8	83.8
2015-16	1354	2576	29	NA	NA	6	370	61.8

(**Source**: Statistical Abstract of Haryana, various years)

In 2014-15, 77.24 percent of the total crops grown in Haryana comprised paddy, wheat, oilseeds and cotton; the total area cropped under paddy and wheat (59.76%) dominated oilseeds and cotton (17.48%). (Agriculture, 2016)

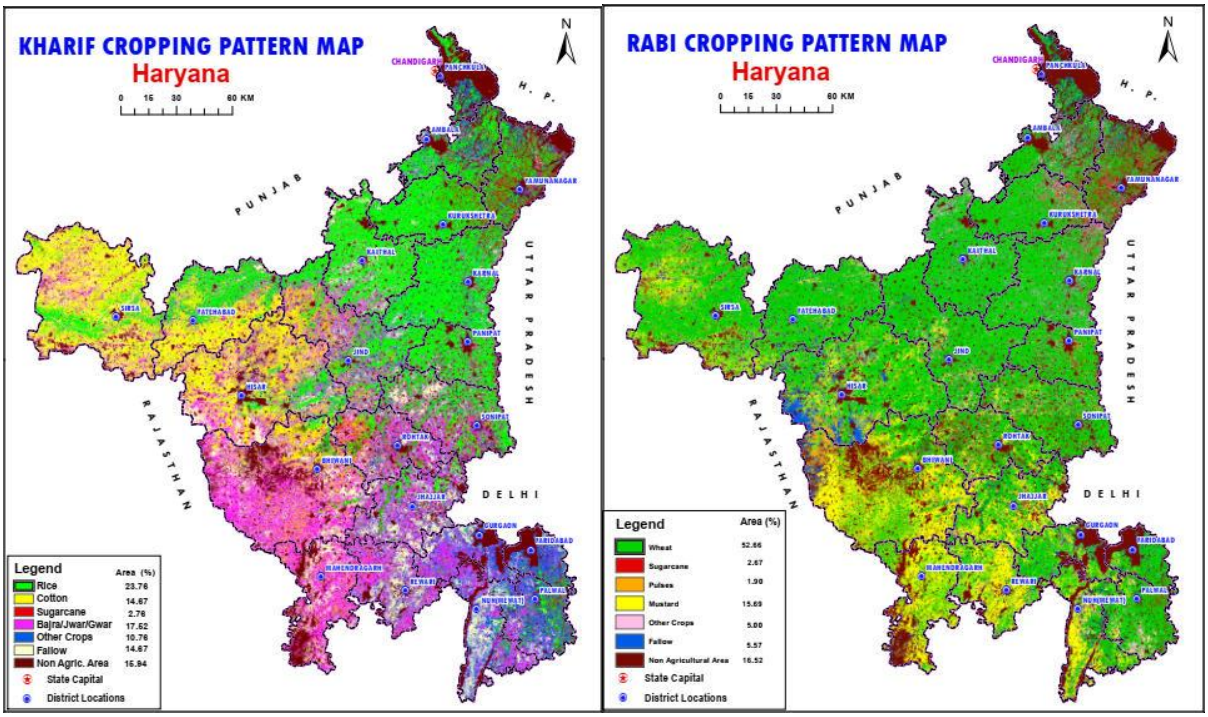
Figure - 2



According to **table 2** and **figure 2** rice, wheat, oilseeds and cotton have all seen increases in acreage under cultivation from 1966-67 to 2015-16; in contrast, land used to grow maize, barley, bajra and pulses has decreased by 1793 thousand hectares during the same period. As a result, Haryana's total arable land and total crop production reflect the state's continued expansion and dominance of paddy and wheat(Agriculture, 2016).

Mono-cropping. . Cropping patterns in the state have shifted dramatically between Kharif and Rabi crops. The major Kharif and Rabi crops have shifted from pearl millet and gram (during 1966–67) to rice and wheat, respectively, in the current period. The paradigm shift to rice and wheat specialization has helped India to secure self-sufficiency in food production and also made her a major global leader in grain export. The area under pulses has decreased since 1980-81, while wheat cropped area has increased. Since 1980-81, the area has shifted from gram to wheat. **Map 1** shows the Kharif cropping pattern of Haryana which indicates that rice and cotton crops are predominant. **Map 2** indicates that around 53% area of the total agricultural land is cropped under wheat crop during rabi season. Rice and cotton replaced bajra, maize, sesame and groundnut. In terms of output growth, wheat, rice and cotton production increased throughout the period. During the 1980s, coarse cereal production and area declined, while bajra production and area increased post-reform. The area and production of maize, barley and bajara decreased (Sihmar & Meena, 2013). Constant mono-cropping degrades the overall soil fertility and thus affects the yield & quality of other crops as well. The implications of mono-cropping on the environment, agriculture sector and farmer's livelihood are elucidated in subsequent paragraphs(Sangwan, 2014).

Map 1 **Map 2**



Source for both maps: Haryana Space Applications Centre (HARSAC)

Declining Underground Water Table. Studies indicate that utilisation of fresh water in Haryana's agriculture sector is over 80 percent of total consumption. "Haryana which has semi-arid climatic conditions is a water deficit state concerning surface and groundwater resources" (Kumar, 2019). No major river system is available in the state. High Yielding Varieties of rice and wheat crop seeds necessitate improved irrigation facilities, increasing farmers' reliance on groundwater resources in the area. The groundwater level in the state is rapidly depleting as a result of over-exploitation through tube well irrigation(John & Babu, 2021). From 1974 to 2018, the state average drop in the water table was more than ten meters. Groundwater is severely depleted in the districts of Mahendergarh, Kurukshetra, Kaithal, Gurgaon, Fatehabad, Panipat, Rewari, Karnal, Fatehabad and Panchkula as a result of overexploitation and paddy irrigation. In Haryana, there are approximately 8.48 lakh tube wells, 2.98 lakh of which are diesel-powered and 5.50 lakh of which are electric-powered. Waterlogging affects 10% of the state's land area. In the near future, groundwater depletion could pose a serious problem(Singh, 2000), so the state government should introduce an Act to regulate the use of underground water in the state, particularly in southern Haryana. Alternative crops should be given more incentives to discourage paddy cultivation. Ambala, Panchkula, Kaithal, Panipat, Bhiwani and Charkhi Dadri districts have had a major decrease in SW monsoon rainfall, while no district has seen a large increase. In terms of yearly rainfall, the districts of Ambala, Panchkula and Panipat exhibit a notable declining trend, whereas no district shows a significant increasing trend.

Table-3 : Status of Groundwater in Haryana

Ser	District	Depth of groundwater (metres)		Fluctuation in groundwater table (metres)
		1974	**2018**	**1974-2018**
1	Mahendergarh	16.11	48.54	-32.43
2	Kurukshetra	9.27	39.11	-29.84
3	Kaithal	6.28	29.33	-23.05
4	Gurgaon	6.64	26.88	-20.24
5	Fatehabad	10.48	29.78	-19.30
6	Panipat	4.56	21.17	-16.61
7	Rewari	11.75	27.31	-15.56
8	Karnal	5.72	19.13	-13.41
9	Faridabad	6.42	18.57	-12.15
10	Panchkula	7.58	17.63	-10.05
11	Y.nagar	6.26	12.70	-6.44
12	Mewat	5.50	11.33	-5.83
13	Palwal	5.37	11.09	-5.72
14	Ambala	5.79	11.44	-5.65
15	Sonepat	4.68	10.23	-5.55
16	Bhiwani	21.24	24.19	-2.95
17	Sirsa	17.88	20.71	-2.83
18	Jind	11.97	14.33	-2.36
19	Jhajjar	6.32	5.24	1.08
20	Rohtak	6.64	4.22	2.42
21	Hissar	15.47	8.08	7.39
	Total	9.19	19.57	-10.38

Source. Groundwater yearbook of Haryana state (various years), central ground water board, the Ministry of Jal Shakti, Govt. of India

Ground Water Pollution.According to the Haryana Kisan Ayog, 'about 65 percent of Haryana's groundwater is of inferior quality.' The groundwater is polluted for many reasons which include untreated industrial effluents and sewage water released into the canal system. However, the use of chemicals (pesticides, herbicides and fertilisers) in agriculture is the major reason for the pollution of groundwater. Haryana ranks 11th in total fertiliser consumption with a total consumption of 1347.4 thousand tonnes of fertilisers in 2015-16(FAO, 2017). Due to excess use of insecticides Pesticides and fertilisers in Rice and wheat crop, ground water of the state got polluted(Bhatt et al., 2016). This polluted water is used in agricultural activities and dairy. This leads to poor foodgrain quality and disease in animals. Degraded food adversely impact human health and cause cancer. Groundwater in some part of the state is unfit for drinking or even for agriculture. It is estimated that half of the groundwater in the state is unsuitable for irrigation because of salinity (E.C.>2000 Micro. Mhos/cm). It is a major concern because it affects large, unconsolidated aquifers, and the problem is exacerbated by the fact that drinking water supplies in densely populated areas are reliant on shallow, polluted aquifers. (M.L. Angurala, 2016).

Diverse weeds. Weeds are unwanted and undesirable plants that compete with the main plant for sunlight, water and nutrients. According to the research conducted across 31 locations (30 European and 1 Canadian) for continuous three years, weed biomass in mixed cropping patterns lowered to an average of 0.62, 0.46 and 0.44 t DM ha1 in years 1–3 post sowing, respectively, compared to the average monoculture (1.45, 2.23 and 2.40 t DM ha1). The average proportion of weed biomass to total biomass was approximately 0.07 in mixtures and 0.33 in monocultures. Weed biomass was not only lower in combinations, but it was also less variable. (Connolly et al., 2018). Monocropping patterns increase the probability of weed invasions, demanding the use of weedicides or herbicides to control them. Thus, continued chemical usage reduces production, decreases resource efficiency and degrades soil health. Many weeds show herbicides resistant properties and required heavy chemical concentration-based herbicides to be used.

The Outbreak of Disease Insects and Pest.The environment of rice and wheat field is humid with very high nutrition in the form of fertilisers. These conditions are favorable for various insects and pests. Farmers act according to the advice of dealers and use heavy insecticides and pesticides. Complex system compound the effect and productivity further decline. Yellow rust disease in wheat has recently become a big issue in Haryana. Similarly, weed management has become a serious issue. Pesticide use has increased significantly, and India has risen to prominence as Asia's leading producer of pesticides (Narayanan et al., 2016). Despite the economic benefits (Gollin et al., 2018), a large amount of pesticides is unnecessary in both industrialised and underdeveloped countries. For example, pesticides in freshwater are an expensive worry, with discovered amounts surpassing statutory limits (Choudhary et al., 2018). Despite lesser pesticide consumption than many other countries, India has substantial pesticide residue. This pollutes water and harms soil. Another big concern is insect attack, which occurs due to pest imbalance. Pesticide use has thrown the balance between predator and prey pests, resulting in an overpopulation of one insect that attacks certain crops. This causes an imbalance in agricultural yield. To combat pests attacking these crops, stronger pesticides or novel insecticides are required. This has disrupted the food chain (Narayanan et al., 2016).

Declining Soil Health. A long-term rice-wheat cropping pattern has taken away several nutrients from the soil, which has led to soil deficiency in those nutrients and a drop in the number of microfauna living there. There has been a lot of damage done to the soil in the state, including soil compaction and waterlogging, as well as multiple nutrient deficiencies, low organic carbon content and a drop in total factor productivity under different production systems(Nawaz et al., 2019). Diversion of agricultural land for non-agricultural use is also becoming more common. Farmers usually apply fertilisers on a periodic basis to compensate for soil nutrient deficiencies. High doses of fertilisers and pesticides have resulted in significant land problems such as soil degradation and soil pollution. Soil microorganisms play a very important role in maintaining soil biological health. The population of these organism increase with increasing crop residue in the soil. An increased population of microorganisms reduces the weed seed bank. Crop residue retention creates natural habitats for these organisms. In the rice-wheat cropping pattern, there is very little time available for the farmer to prepare his field for the wheat crop. Farmers burn rice crop residue for preparing the field for sowing wheat. Burning of rice stable degrades the soil health at an alarming rate. Land conservation is necessary not only for Haryana's farmers and rural communities but also for the country as a whole to achieve sustainable agricultural development.

Residue management. Haryana is often referred to as the "Food Mine" of the country because of its abundance of produce. As a result, the production of crop residue (27.83 MT) is obvious (NPMCR, 2017). Management of rice crop residue is a major challenge in front of farmers as well as society. Wheat crop residue is used as animal feed however, rice crop residue is not suitable for animal feed due to the high silica content present in rice straw. The loss of soil organic matter caused by the removal of wheat crop residue is detrimental to soil health, but it is required in order to feed livestock and maintain mixed farming. A narrow window of time between paddy harvesting and wheat sowing is one element that encourages farmers to choose a low-cost and simple method of disposing of paddy straw. Almost ten thousand tonnes of excess crop residue were burned in the fields of Haryana (NPMCR, 2017). Burning the rice crop residue is the most common practice adopted by farmers. Heavy metals (HM) and dioxin are released as a result of this process. A wide range of pollutants is released into the atmosphere when biomass is burned, resulting in a degradation in air water and soil quality(Nawaz et al., 2019). It leads to loss of organic matter, nutrients and soil biota, causes air pollution and associated, ill effects on human and animal health.

Pulses Crises. According to a report published by the Ministry of Finance, India had a "pulses crisis" in 2014-15 and 2015-16, when the productivity of pulses dropped because of weak monsoons. This caused a sudden surge in demand and an increase in the price of pulses for consumers. Pre-Kharif sowing prices and a good monsoon led to a big rise in pulse acres. In India and other places where there has been a big increase in the amount of food available, prices started to fall. The report says that pulse farmers and consumers will benefit from an immediate and appropriate increase in the MSP for pulses. This will help both groups in the long run. Crop diversification could be a way to fight the agricultural economy's decline and keep the soil's fertility (Ministry of Finance, 2016).

High Energy Requirement. It takes a lot of energy to grow rice, whether it comes from human labour, input materials (like fertiliser and pesticide), or power sources (like fuel, machinery and electricity), for a variety of operations such as preparing the seedbed, sowing the seeds, transplanting, fertilising and controlling insects(Soni et al., 2018). Deeper water for irrigation in rice and wheat necessitates the use of more energy. Electricity used for irrigation through tube wells is given a large state subsidy by the state government. Consequently, the industrial sector experienced power shortages. Subsidized electricity encourages rice and wheat monocultures.

Decreased Land & Water Productivity. There is a rice-wheat cropping system in place on farms, and farmers aren't interested in changing it. Since the late 1980s, the land and water productivity of all crops has increased more than twice as much as it was. Rice and wheat crops' land and water production have been steadily decreasing despite an increase in total cropped area. It is widely accepted that farmers' crop selection decisions are influenced by higher return values in the growing cropping system. The ecosystem suffers as a result of government programmes to increase land and water productivity through high-yielding varieties and improved irrigation. Because it has a direct impact on agricultural production, the new cropping system is not sustainable(Rani, 2019). As a result, key crops' land production has declined.

Poor Income of Farmers. By using HYV/Hybrids, production and protection technologies, as well as the proper infrastructure and policies, many notable accomplishments were made possible. crop varieties/hybrids have had a major impact on agricultural productivity. However, despite all this, rice and wheat crops are experiencing stagnation in yields. The adverse climatic condition and poor soil health are the major factors that lead to decreased yields. Landholding size shrinks generation after generation which increases per hectare input cost. It also increases due to the heavy use of insecticides, pesticides and fertilisers. HYV seeds of rice and wheat crops required frequent and timely irrigation. Farmers are required to spend a significant

portion of their income to gain deeper underground water. According to the Department of Agriculture and Cooperation, paddy and wheat cultivation costs have been increasing at a 10% annual pace due to an increase in labour costs, which now account for up to 50% of overall production costs for crops such as paddy. All these factors lead to poor income for farmers. They borrow money from local money lenders at a high-interest rate at the stake of their agriculture production. The situation became worse if production is not as per expectations. They got trapped in this vicious cycle of money lenders.

Change of Dietary Habits. The increasing replacement of traditional crops such as maize, jowar and bajra notonly disturbed the dietary habits in rural areas but also raised economic constraints on poor and marginalised people by abstaining them from obtaining affordable sources of nutrition. The unabated use of pesticides and fertilisers has been causing serious health problems tothe farmers and consumers as well(FAO, 2017).

Environment Pollution. The agriculture sector is usually identified as a major source of Greenhouse Gases (GHG), accounting for around 24 percent of total global anthropogenic GHG emissions (IPCC 2014). Mechanised harvesting, increased residue production and excessive groundwater use all lead to an increase in Rice Crop residue burning. The quality of the air in Haryana during the Diwali season is highly dependent on the amount of residue burning there, leading to haze-like conditions in the area (Ravindra et al. 2020). Rice crop residue burning has a significant impact on Haryana's air quality. According to research, Haryana's annual mean PM10 and PM2.5 concentrations exceed national ambient air quality standards by a wide margin. All districts in Haryana have their own unique set of air pollution problems, as evidenced by the findings, which show wide regional disparities in air quality. Apart from the environmental impact, it has a detrimental effect on rural residents, causing respiratory problems, tuberculosis and decreased visibility. Additionally, it reduces soil productivity by oxidising essential nutrients within the soil (Singh et al., 2018). Farmer education programs about the long-term negative effects of crop residue burning on the soil environment and human health are recommended. Because of this, farmers will begin using alternative crop residue management methods. To improve accessibility, it is also necessary to provide village or community management machinery, technical support and financial assistance.

Conclusion. Based on the foregoing discussion, it can be concluded that the cropping pattern of the state has shifted towards specialised rice and wheat crops between 1966 and 1967 and 2015–2016, with jowar, barley, maize and bajra losing their prominence in the state during the two periods. The total area under cultivation, as well as the total production of wheat and rice, has increased by orders of magnitude. Both of these crops are extremely water-intensive and the state is extracting more and more groundwater for irrigation purposes through tubewells as a result. As a result, groundwater levels in the state have dropped to dangerously low levels. According to the findings of the study, excessive use of herbicides, pesticides and fertilisers in rice and wheat crops harms soil health and groundwater. In comparison to a mixture, the average weed biomass in a monoculture is found to be higher. The management of paddy crop residue is a major challenge for farmers as well as for society as a whole. Farmers consider burning to be the most convenient method of removing residue, but this practice contributes to environmental pollution. Monocropping is also a significant contributor to the pulses crisis. A combination of high input costs, stagnant productivity and slowly increasing selling prices has resulted in a continuous decline in the profit margin of rice and wheat production. Multiple cropping patterns must be promoted through public awareness campaigns and government initiatives in the coming years. There should be a concerted effort on the part of the various stakeholders to draw attention to the negative consequences of rice-wheat monocropping and to promote multiple cropping that is appropriate for each agroclimatic zone.

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