CROP YIELD GAP ANALYSIS PAKISTAN|2020

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Introduction

Agriculture is considered the backbone of Pakistan's economy, which relies heavily on its major crops. It directly supports the country's population and accounts for major portion of gross domestic product (GDP). The major agricultural crops include cotton, wheat, rice, sugarcane, fruits and vegetables. Pakistan's principal natural resources are arable land and water. Agriculture accounts for about 18.9% of Pakistan's GDP and employs about 42.3% of the labor force. In Pakistan, the bigger agricultural province is Punjab where wheat and cotton are the most grown crops. Mango orchards are mostly found in Sindh and Punjab provinces that make Pakistan the world's 4th largest producer of mangoes. The most important crops are wheat, sugarcane, cotton, and rice, which together account for more than 75% of the value of total crop output.

Wheat

In the wheat production system, Punjab, which is Pakistan's irrigated province, has had a historical focus on a green revolution in wheat. During the 1960s, the Green Revolution in Pakistan also involved public investment in irrigation canals and market development (Renkow, 2000). The rural society and wheat production were transformed; the anticipation of starvation retreated. Despite this applauded improvement, the sustainable production of wheat remained the primary focus of Pakistan's population. The government of Pakistan still needed improvements for the production of wheat in different varieties. Previous research on the wheat crop has shown a slow growth rate of crop variety replacement by farmers in promoting new varieties of wheat in Pakistan (Heisey, 1990, Iqbal et al., 2002). In 1997, an estimated area of one million hectare was used for wheat production, which was 51 percent of the entire wheat area in Pakistan (Smale et al., 2002).Wheat crop production increased by 2.5 percent to 24.946 million tonnes over last year’s production of 24.349 million tonnes. The area under cultivation increased by 1.7 percent to 8,825 thousand hectares over last year’s area (8,678 thousand hectares).

Rice

Pakistan plays a major role worldwide as a rice exporter, and it annually exports approximately 2 million tons, which is 10 percent of the world's trade. In Basmati rice, Pakistan's share is approximately 25 percent of total exports. Rice exports are the second highest source of income in Pakistan. Rice grains fulfill approximately 60 percent of the population of Pakistan's food needs, and rice is a potential source of food worldwide for animals during the winter (Drake et al., 2002, Nguyen et al., 2008). The usage of pesticides increased after the 1950s, when 250 metric tons of pesticides were imported for greater improvement of production. Its usage increased by 2158.6 percent from 1952 to 2004 (Khan et al., 2010).During 2019-20 cropped area of 3,034 million hectare increased by 8.0 percent compared to 2,810 thousand hectares of last year. The production increased by 2.9 percent to 7.410 million tonnes against 7.202 million tonnes of last year due to an increase in area under the crop, driven in part by higher domestic prices and availability of inputs on subsidized rates.

Cotton

Pakistan is the world's largest producer of raw cotton. In 2011–2012, Pakistan ranked as the 4th largest cotton producer, with a 9.81 percent share in global cotton. In the same period, Pakistan's yarn exports contributed 26.1 percent and 14.3 percent to the global market. Cotton exports accounted for 46 percent of Pakistan's total exports and provided 35 percent employment to the labor force (FAO, 2012, GOP, 2012). The Pakistan Central Cotton Committee has aimed to increase the production of cotton. However, evidence has shown that insufficient irrigation water is one of major problems in agricultural production in Pakistan. Farmers commonly apply water to furrowed fields by flood irrigation, resulting in low agriculture water productivity (Kahlown et al., 2007). During 2019-20, cotton was sown on an area of 2,527 hectares, which increased by 6.5 percent over last year's area (2,373 hectares). Cotton production is estimated at around 9.178 million bales, which is lower by 6.9 percent over the last year's production of 9.861 million bales. Even though the overall area increased over last year, the overall performance remained below due to unfavorable weather and low water availability during important stages of plant development along with pest attacks.

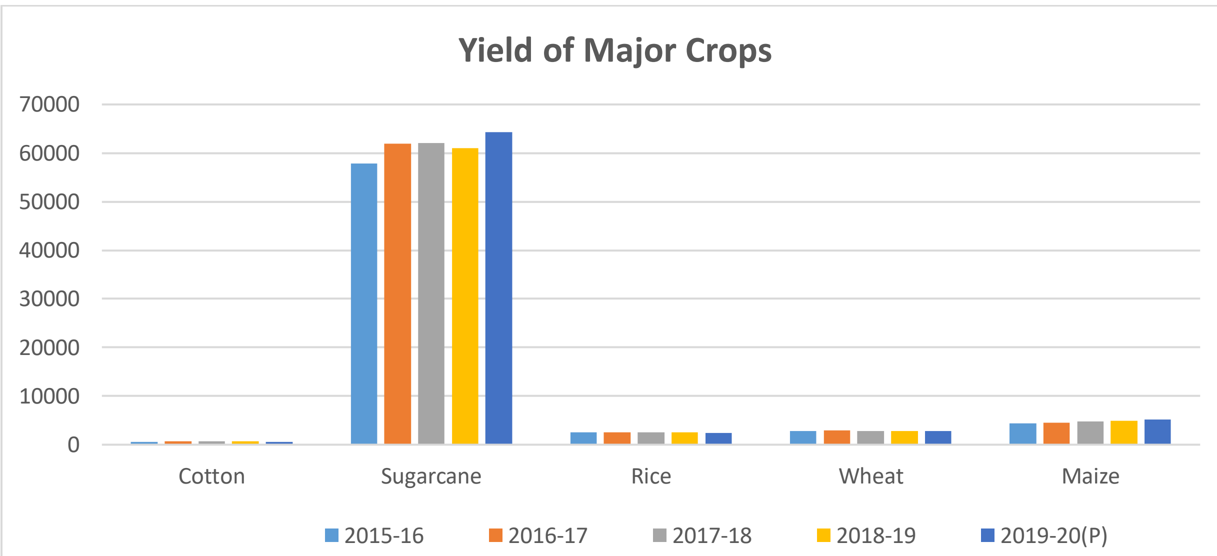
Maize

Maize is another cash and food crop of Pakistan, serving as feed as well as silage, and it is a high yielding cereal crop globally. After wheat, rice and cotton, maize is the fourth chief cereal crop of Pakistan. It is mainly sown in two seasons: spring and autumn. In spring, it is planted from February to March, while for autumn, maize is grown from July to August. The maize life cycle depends upon the availability of water; the water discrepancy at any phonological stage, i.e., reproductive and maturity stages, has several retorts and can damage the grain yield. Previous research (Heisey and Edmeades, 1999) has shown that drought stress causes grain yield damage when it occurs in the reproductive stage of the crop's life cycle. During 2019-20, maize was cultivated on thousand hectares and recorded an increase of 2.9 percent over last year's 1,374 thousand hectares. Its production increased by 6.0 percent to 7.236 million tonnes compared to last year's production of 6.826 million tonnes. The production increased due to increase in area and availability of improved variety of seed as well as better economic returns.

Sugarcane

Sugarcane is a high-value cash crop of Pakistan and is quite important for sugar-related production. It accounts for 3.4 percent of additional agricultural value and 0.7 percent of the gross domestic product (GDP). As a sugar crop, sugarcane is the chief biofuel crop worldwide (Robinson et al., 2011). The slow growth rate of sugarcane in the early stage provides space and resources for intercropping in the field. Many studies have shown that sugarcane intercropping with other crops, such as peas, watermelon and onions, could decrease the yield of sugarcane and could increase economic income significantly (Al-Azad and Alam, 2004). During 2019 sugarcane production decreased by 0.4% to 66.880 million tonnes as compared to 67.174 million tonnes of last year. The output may depict the pattern of cultivation i.e 1,040 thousand hectares compared to 1,102 thousand hectares, a decline of 5.6 percent, with improved yields compared to 2018-19.

The graph below depicts the performance in terms yield of major crops of Pakistan for past five years. It is evident from the graph that the sugarcane yield was highest as compared to other crops. And the performance of cotton crop is least. While rice, wheat and maize yield is more than cotton but far less than sugarcane.



Source: Economic Survey of Pakistan 2020

Yield Gaps

The concept of yield gaps has increased considerably in the literature in the past few years. The yield gaps of crops grown in certain locations and in cropping systems represent the differences between the optimum possible yields under optimal management and the average actual yields attained by farmers (Van Ittersum and Cassman 2013). The potential yield is the yield level under optimum management of fully irrigated or water limited yields under rain fed conditions and effectively controlled biotic stresses. Unjustified food security has many roots (Barrett 2010); however, regions with low food security also have a tendency to have yield gaps in their potential and actual yields

Yield gaps are especially large in developing countries, where small landowners dominate agricultural lands (Mueller et al. 2012). Closing global yield gaps through better nutrient and water management can potentially double worldwide food output and would go a long way to meet food security goals (Zhang et al. 2016). As the average agricultural production approaches the threshold level of the potential yield, it becomes more challenging for growers to sustain production increases because further improvements are needed to eliminate small inadequacies in the unified management of crops, soils, nutrients, irrigation water, insects and pests (Kong et al. 2019). Generally, this laborious adjustment is not economically feasible at the production scale, so production stagnation usually occurs when the average agricultural yield reaches approximately 80% of the upper limit of the potential yield.

Globally, achieving sustainable food supplies is one of the humankind's major challenges and has captured public attention over the past several years (Duan et al. 2019). Fulfilling future food demands without degrading the earth's ecosystems is a crucial challenge for humankind. As urbanization and economic development will increase the per capita consumption of livestock products, it is expected that in developing countries, food demand will grow faster than population growth in areas where greater than 95% population growth is projected (Cassman et al. 2003).

To balance the global food demand driven by income and population growth, crop yields must increase substantially (Van Wart et al. 2013). The proposed demand for a 60% increase in agricultural outputs by 2050 is very large but is not unprecedented (Rosegrant et al. 2001). In some highly productive areas, the areas of cultivated land are underestimated. Producing sustainable food to supply the world's growing population is a challenge (Godfray et al. 2010), and narrowing the production gap is a crucial strategy to address this challenge. Any prediction of future global crop production will include many uncertainties and will inevitably emphasize some potential causative factors over others (e.g. pathogenic factors).

According to the 6th Population and Housing Census of Pakistan (2017), the country's population is growing at a rate of 2.4% per annum (GoP 2017–2018). The population of Pakistan is projected to be 228.9 million in 2025 and 250.2 million in 2050. This rapid growth in population has increased food demand and urbanization and has decreased available land resources, especially arable land resources. According to the global food security index, Pakistan has an overall score of 49.1 and an affordability index of 47.6 and ranks 77th in the world, with 22% of its population being undernourished (Unit 2013). The agricultural sectors of Pakistan should place an emphasis on their potential productivity to meet the challenges of fulfilling the demands of its ever-growing population for food and fibre (Byerlee and Ali 1999).

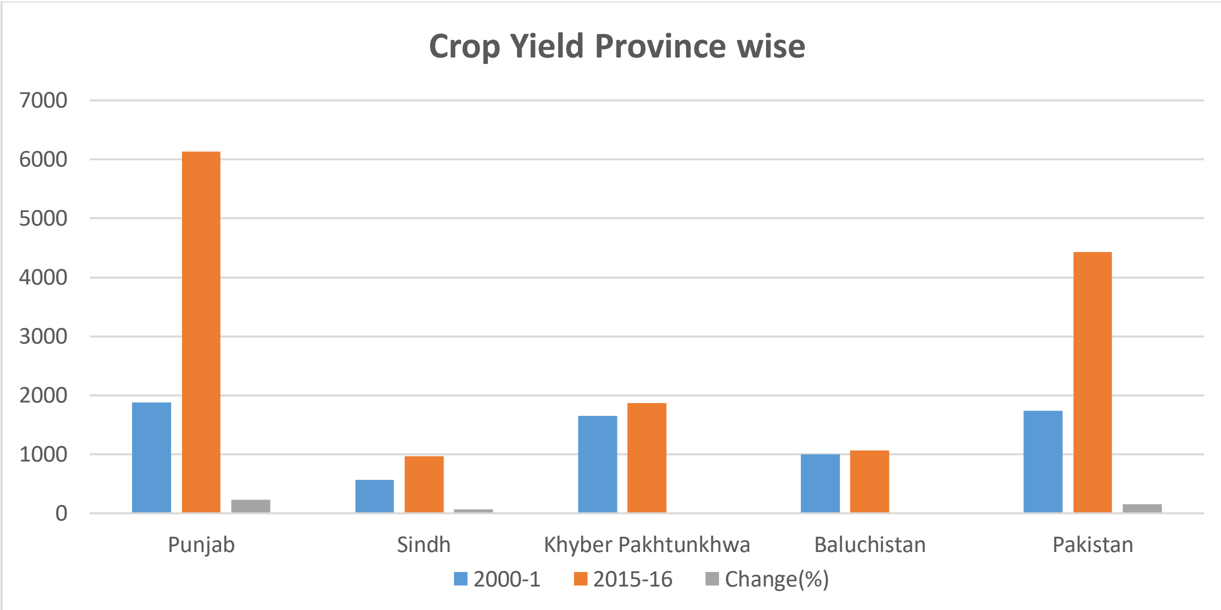
The increasing potential for food productivity, as a reference to make food policy and carry out arable land protection strategies, is analyzed by comparing potential food productivity and actual food production. To meet the growing demands for water, food, consumer goods and other utilities for more than 6 billion people worldwide, natural resources, including land resources, have been transformed, and more forest lands have been converted into farmland (Khan et al. 2019b). Due to rapid population growth and urbanization, land use has undergone an undesirable transformation, which has affected the production and yields of many crops.

Globally, urban areas, farmland and pastures have expanded over recent decades, with a considerable increase in the consumption pattern, water and fertilizer and with a substantial loss of biodiversity. Land use changes are crucial in environmental management and suburban area planning (Banzhaf et al. 2017); however, land use changes play an inevitable role and contribute to overall climate change and biodiversity loss (Chen et al. 2001).

To meet the second sustainable development goal of the United Nations, e.g. to overcome hunger, achieve improved nutrition and food security and encourage sustainable agriculture, requires increased yields in many regions, including Pakistan (Akram et al. 2018). Agricultural production can be increased through arable land extension or agricultural intensification (Tilman et al. 2011). Increasing production in poorer countries will necessitate substantial investments in innovation to adapt to new soil types, climate, pests (Licker et al. 2010) and infrastructures (Foresight 2011). Thus, it is meaningful to methodologically estimate potential grain productivity at the present level of technology. The main objectives of this study are to perform yield gap analysis in the field and to identify key components and their associated uncertainties in the output gap analysis to generate locally relevant results that can be aggregated into regional or country estimates.

Production and yield gap analysis of major food crops

Growth in the agricultural sector is contingent upon favorable weather conditions. There is a strong relationship among agriculture and climate, temperature, precipitation, floods and other aspects of weather that ultimately affects economic performance, including agricultural production, commodity prices and, finally, economic growth. Despite the technologically advanced period of today, weather is still a key factor that determines agricultural productivity, whereas rainfall and temperature act as core drivers for crop production and, consequently, rural food security (Khan et al. 2020). In spite of the so-called favorable conditions of its soil, irrigation water and climate, agriculture in Pakistan suffers from underutilization of its potential resources, thus resulting in unnecessarily low yields per hectare and per unit of water consumed.



A recent study shows that the national potential of total grain production is 100,933 000 kg and the actual national grain production from 2015 to 2016 was 38,227 000 kg, for a difference of 62,706 000 kg. The potential grain production of Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan provinces in Pakistan is 71,614 000 kg, 16,101 000 kg, 9227 000 kg and 3992 000 kg, respectively, and the actual total grain production for these provinces is 27,838 000 kg, 6451.7 000 kg, 2454.9 000 kg and 1481.3 000 kg, respectively, while the total production gaps are 43,776 000 kg, 9649.3 000 kg, 6772.1 000 kg and 2510.7 000 kg, respectively.

The potential production levels presume that water and nutrients are adequate while crop disease, weeds, insects, pests and other agricultural practices are optimal to mimic yield levels (Lv et al. 2017). The prevailing global agricultural expansion track will have serious, long-term impacts on the environment (Tilman et al. 2011). Given the prerequisites for sustainable intensification, it is crucial to identify regions with a high crop yield potential to increase food supplies (Van Ittersum et al. 2013). Generally, the potential grain yield gradually decreases from southwest to northeast, including Balochistan and Khyber Pakhtunkhwa provinces.

Province	Total seeded area (000 ha)	The potential production of total grain (000 kg)	The actual production of total grain (000 kg)	Production difference (000 kg)	Potential yield (kg/ha)	Actual yield (kg/ha)	Yield difference	Rate of exploitation
Punjab	10,098	71,614	27,838	43,776	7092	2757	4335	0.39
Sindh	1945	16,101	6451.7	9649.3	8280	3318	4962	0.40
KP	1341	9227	2454.9	6772.1	6880	1831	5049	0.27
Balochistan	596	3992	1481.3	2510.7	6693	2484	4209	0.37
Pakistan	13,980	100,933	38,227	62,706	7220	2734	4486	0.3

Above table also shows that the potential grain yields in these four provinces (e.g. Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan) were 7092 kg/ha, 8280 kg/ha, 6880 kg/ha and 6693 kg/ha, respectively, and that the actual grain yields were 2757 kg/ha, 3318 kg/ha, 1831 kg/ha and 2484 kg/ha, respectively, from 2015 to 2016, whereas the yield gaps per unit area were 4335 kg/ha, 4962 kg/ha, 5049 kg/ha and 4209 kg/ha ,respectively.

The historical evidence proves that food production in Pakistan has increased by almost 50% over the past 20 years. However, the agricultural sector, in general, and the crop sector in particular, are considered to be working at far below their genuine potential yield. The yield gaps are also expected to be relatively large in developing countries, for which input prices are relatively high because of market poor dealer networks, high transportation costs and small market sizes.

The exploitation rate of potential productivity in Pakistan was 0.38 in 2015–2016, while there were differences in the exploitation rate of potential grain productivity among the provinces. Punjab and Sindh provinces have higher exploitation rates of the potential total grain yield than the nation overall and thus have little space left for further improvement in their total grain production. Khyber Pakhtunkhwa and Balochistan provinces have lower exploitation rates of the grain yield than the national level and have a certain space for improving total grain production.

The table below demonstrates the provincial and national potential yields, actual yields and yield gaps of the major food crops. The national potential grain yields of wheat, rice and maize are 6681 kg/ha, 9267 kg/ha and 7184 kg/ha, respectively, while the actual national grain yields of wheat, rice and maize are 2780 kg/ha, 2483 kg/ha and 4425 kg/ha, respectively. The resulting national yield gaps of wheat, rice and maize are 3909 kg/ha, 6784 kg/ha and 2759 kg/ha, respectively.

(kg/ha)

Province	Potential yield of wheat	Potential yield of rice	Potential yield of maize	Actual yield of wheat	Actual yield of rice	Actual yield of maize	Yield gap of wheat	Yield gap of rice	Yield gap of maize
Punjab	6825	9443	8245	2825	1967	6132	4000	7476	2113
Sindh	6851	11,113	6865	3322	3574	973	3529	7539	5892
KP	6548	8512	7500	1814	2377	1863	4734	6135	5637
Balochistan	6500	8000	6125	2276	3276	1069	4224	4724	5056
Pakistan	6681	9267	7184	2780	2483	4425	3901	6784	2759

Sindh Province has high potential and actual yields of wheat and rice crops, followed by Punjab Province, where the agricultural land is very fertile with good irrigation systems. Similarly, Punjab and Khyber Pakhtunkhwa provinces have high potential yields of maize and should increase with maize cultivation. The yield gap of wheat crops is high, e.g. 4734 kg/ha, in Khyber Pakhtunkhwa, followed by 4424 kg/ha in Balochistan, 4000 kg/ha in Punjab and 3529 kg/ha in Sindh. All the provinces except for Sindh Province have a higher yield gap of wheat than the national yield gap of wheat. Sandhu (1993) also reported that there is a considerable potential gap in the yields of wheat, rice and maize, sugar cane, rapeseed and potato.

The table also displays that the yield gap is high in Sindh Province, followed by Punjab, Khyber Pakhtunkhwa and Balochistan provinces, whereas the yield gap of the maize crop is high in Sindh Province, followed by Khyber Pakhtunkhwa, Balochistan and Punjab provinces. The yield-limiting factors might involve agronomic, infrastructural and socioeconomic conditions (Zhang et al. 2016)

To overcome food insecurity, Pakistan should emphasize reducing the yield gap of the major food crops and bringing more of the moorlands of Balochistan Province under wheat cultivation. To close the yield gaps, agricultural management should be considered in the context of climate change that is projected to considerably influence agricultural productivity (Lobell et al. 2011) and induce adaptation management (Howden et al. 2007). Specifically, a major issue is how variations in water availability may conflict with the expected irrigation requirements for closing yield gaps (Mueller et al. 2012). Previous studies have also revealed that the food demand is rapidly increasing and that most of the world’s current farmland production is far below its potential (Tilman et al. 2011).

The recent researches estimated the areas under cultivation, actual production and yields of major food crops from 2000–2001 to 2015–2016 on a national basis and reveals that the yields of all the major food crops increased considerably on a national basis from 2000-2001 to 2015-2016. These findings revealed that increases in the maize yield over time are more dominant than those of other food crops, although more planting area is plotted with wheat and rice crops as wheat is the main staple food of the country.

The country’s food supply remains highly dependent on good yields rather than on any institutionalized process of technical change and is, therefore, vulnerable to sharp recessions (Gizewski and Homer-Dixon 1996). Despite the substantial enhancements made over recent decades, the rates of under-nutrition remain high in South Asia (Gillespie et al. 2019).

The table below shows provincial and national comparisons of the areas under cultivation, total potential production, actual production and production gaps of wheat, rice and maize crops. On a national basis, the total areas under wheat, rice and maize crops from 2015 to 2016 were 9224 ha, 2739.5 ha and 1191 ha, respectively. The national total potential production of wheat, rice and maize crops was 62,645.67 000 kg, 26,758.69 000 kg and 9461.16 000 kg, respectively, and the actual production was 25,633.10 000 kg, 6801.3 000 kg and 5270.9 000 kg, respectively, whereas the subsequent national production gaps of wheat, rice and maize were 37,012.57 000 kg, 19,957.39 000 kg and 4190.26 000 kg, respectively.

	Punjab	Sindh	Khyber Pakhtunkhwa	Balochistan	Pakistan
Total cultivated area under wheat (000 ha)	6913.9	1154.6	772.3	382.9	9224
Total potential production of wheat (000 kg)	47,189.63	7910.16	5057.02	2488.85	62,645.67
Total actual production of wheat (000 kg)	19,526.7	3834.6	1400.50	871.30	25,633.10
Total production gap of wheat crop (000 kg)	27,662.94	4075.56	3656.52	1617.55	37,012.57
Total cultivated area under rice (000 ha)	1780.2	719.8	64.7	174.8	2739.5
Total potential production of rice (000 kg)	16,810.43	7999.14	550.73	1398.40	26,758.69
Total actual production of rice (000 kg)	3502	2572.8	153.8	572.7	6801.3
Total production gap of rice crop (000 kg)	13,308.43	5426.34	396.93	825.70	19,957.39
Total cultivated area under maize (000 ha)	716.1	3.7	468.5	2.9	1191
Total potential production of maize (000 kg)	5904.24	25.40	3513.75	17.76	9461.16
Total actual production of maize (000 kg)	4391.2	3.6	873	3.1	5270.9
Total production gap of maize crop (000 kg)	1513.04	21.80	2640.75	14.66	4190.26

Several anthropogenic and biophysical constraints are responsible for the low yields in the country. For instance, due to the rapid population increase and urbanization, agricultural lands, dense forests and water bodies have been depleted, which, in turn, exert great pressure on agricultural production (Khan et al. 2019c; Khan and Zhao 2019). Arifullah et al. (2009) reported that agricultural production in Pakistan is highly erratic in that one good year is either preceded or followed by bad year(s). Apart from economic constraints, there may also be environmental reasons (e.g. uncertainties related to temperature and rainfall) that prevent farmers from producing at feasible yield levels (Van Ittersum and Cassman 2013). The literature has revealed that compared to the best inbred varieties, hybrid rice can boost potential yields by 7–10% (Duvick and Cassman 1999), 9% and 10–20% (Hengsdijk and Langeveld 2009). The adoption of hybrid wheat may also boost the potential yield of wheat crops, but due to the high cost of seed production, hybrid wheat remains in the experimental phase. The introduction of hybrid maize varieties has been successful, and although there is some debate over the progress in potential yields of maize hybrids, they respond better to fertilizers and have higher plant densities, which result in higher average farm yields .In conclusion, converting to hybrids may provide a one-time enhancement to the potential yields of many crops.

Pakistan comparison with other countries

According to the Statistical Book 2011 of the United Nations Food and Agriculture Organization (FAO) reveals that Pakistan is way behind in wheat, rice, sugarcane and pulses production, both globally and regionally. According to experts, water shortage, absence of high yield verities of seeds, and lack of research and development are the basic causes of low per hectare yield of crops in Pakistan. The two consecutive floods in 2010 and 2011 have also disrupted the agricultural productivity of the country. The FAO report released last week relates to authenticated data up to year 2010.

Pakistan is among the top ten producers of wheat with around 24 million tons output in 2010, but it’s per hectare yield of 2.6 tons pales in comparison with over 115 million tons wheat produced by China with per hectare yield of 4.7 tons. India obtains 2.8 tons wheat per hectare, Bangladesh 2.4 tons. The United Kingdom with wheat yield of 7.7 tons per hectare is top in productivity but its wheat cycle is spread over one year against five months in Pakistan, the report said.

In rice, Pakistan with average productivity of 9 million tons is among the top 12 producers and it's per hectare rice yield is 3.1 tons. China again is the largest producer of rice with an output of 197 million tons with per hectare yield of 6.5 tons, Bangladesh obtains 4.2 tons rice per hectare, Sri Lanka 4.1 tons per hectare and even India with rice productivity of 3.3 tons per hectare is ahead of Pakistan, the FAO report said. In coarse grains China produces 5.2 tons per hectare, Pakistan 2.2 tons per hectare and India only 1.2 tons per hectare. Italy with per hectare yield of 7.6 tons per hectare is the productivity leader in coarse grains. China produces 0.6 tons per hectare of oil crops while India and Pakistan produce 0.3 tons per hectare. The leader in oil crops production is Malaysia that obtains 4.5 tons of oil crop per hectare.

Pakistan produces 1.1 million to 0.9 million tons of pulses per year with per hectare yield of 0.6 tons which is the lowest in the region. China produces 4.4 million tons pulse per annum at 1.2 tons per hectare which is twice that of Pakistan. Per hectare production of pulses in Bangladesh is 0.9 tons while it is 0.7 tons in India. India though is the largest producer of pulses in the world with total annual production of 17.11 million tons. The highest per hectare yield of pulses is 3.9 tons which is obtained by the United Kingdom.

In roots and tuber production Pakistan is on top in productivity with per hectare yield of 21.6 tons but it is far below the world best of 42.1 tons obtained by the United States of America. India produces 20.6 tons roots and tuber per hectare, China produces 17.8 tons per hectare and Bangladesh 17.7 tons per hectare. Pakistan's sugarcane production of 52.4 tons per hectare is slightly higher than that of Bangladesh that obtains 43.8 tons of sugarcane per hectare. India with per hectare yield of 66.1 tons is the leader in sugarcane productivity in the region followed by China that obtains a yield of 65.7 tons per hectare.

The FAO report (2014) highlighted the reasons for the low yield in Pakistan in comparison to regional countries as well as globally: water shortage, absence of high yield varieties of seeds and lack of research and development. However, in this context it is relevant to note that FAO's data takes account of the national average while the yield per hectare of different crops varies from province to province.

Punjab remains the food basket of the country and its yield is on average higher than the national average. Additionally, within provinces yield varies markedly between subsistence farms and those operated by the rich landlords whose yield per acreage is closer to the regional average. Be that as it may, it is also relevant to note that the Indian Punjab has a higher yield per hectare in most crops relative to the Pakistani Punjab.

Pakistan produces 3.1 tons of wheat from one hectare, which is just 38% of the 8.1 tons produced in France - the world's best productivity. Similarly, Pakistan produces 2.5 tons of cotton per hectare, which is 52% of the 4.8 tons produced in China. Sugarcane yield stands at 63.4 tons per hectare in Pakistan, which is 51% of the 125.1 tons Egypt produces from every hectare while maize productivity is estimated at 4.6 tons per hectare, 41% of the 11.1 tons that France is producing. In the case of rice crop, Pakistan produces 2.7 tons from every hectare, which is merely 29% of the 9.2 tons per hectare in the US.

What is perhaps required is for the provincial governments, given that agriculture is a provincial subject, take cognizance of their farm sectors and initiate appropriate measures based on studies in high yield countries on how to increase yield. Assistance in this regard can be sought from China, the US and the UK as well as Brazil the world leaders in yields in specific crops. Brazil is the largest global producer of sugarcane with total output of 719 million ton at 79.2 ton per hectare. The highest sugarcane yield is obtained by Columbia which produces 118.1 ton per hectare, the FAO report said.

The challenges in crops productivity and yield

Agriculture is one of the most climate-sensitive sectors of an economy. It responds to temperature, precipitation, soil radiation, etc., which are directly associated with climate change. Rising temperature, uneven distribution of precipitation, floods, droughts, and other climatic disasters have affected human life along with socio-economic sectors of the world's over-populated regions, i.e., South Asia. The assessment of the ultimate economic effect of climate change on producers, consumers, and other agriculture-related agents requires a detailed evaluation of economic impacts using inputs from a different climate and crop models.

To study the potential impacts of changing climate, scientists and crop experts carried out integrated and collaborative research. They have used global climate models that analyze the interaction of weather variables using different physical, biological, and chemical principles and then estimate their responses to rising levels of greenhouse gas emissions in the atmosphere. These models also consider different socio-economic projections, including income and population growth, energy use, and industrial growth to predict earth's future climate. These global climate projections are then used by bio-physical scientists in different crop models to simulate biological processes of crop growth and productivity. They provide the estimated impact of climate change on crop yield and human health.

These models overcome the requirement of time-consuming and expensive field surveys and experimentation to analyze the effects of weather variability on agriculture. Moreover, they can be easily used with different economic models to study the economic impacts of climate-induced- change in crop production. Two most commonly used models are Decision Support System for Agro-technology Transfer and Agricultural Production Systems Simulator. The potential impact of weather conditions on crop production through biophysical models can be used as input in different partial and general equilibrium economic models to analyze the economic response of climate change by different socio-economic agents of society.

The fifth annual report of the Intergovernmental Panel on Climate Change states that mean yearly temperature of South Asia will increase by 3.3 ^{0}C by the end of 21st century under Multi-Model Data regional climate model. A significant amount of research portrays the poor state of the agriculture sector of South Asian economies, due to extreme climate events. This sector will have difficulty providing food security to the rising population of the region. As more than 60% of the total population is involved in agricultural activities, loss of agricultural production, due to climate change is of serious socio-economic concern. Pakistan is one of the most climate-sensitive nations despite the fact that it contributes merely 0.8% to atmospheric Greenhouse Gases, which places Pakistan at the 135th position in comparison to the other countries.

Global climate risk index 2017 ranks Pakistan at number 7 in the list of most vulnerable nations due to its geographical and climatic features. It lies in the geographic region where an increase in temperature is predicted to be higher than global average temperature, where glaciers, the only source of feeding rivers, are receding rapidly and most of the land is arid and semi-arid. More than 40% of the population in this region is involved in agricultural production. Variability in the monsoon rains, massive floods and droughts further add to its vulnerability. The cumulative effect of all these climate peculiarities puts the country in a severe threat of food, water and energy security.

Empirical literature based on crop modeling in Pakistan reports that production of its major cereal crops is prone to high temperature and low rainfall. Cropping seasons in Pakistan require a certain amount of heat and precipitation. Average temperature remains moderate during the wheat growing season. However; wheat does not receive enough rainfall to grow effectively. Most of the cultivated land is fed with irrigation water and post-monsoon rainfall. According to Pakistan economic survey 2016-17, 30% of the total cultivated area of the wheat crop is irrigated with canal water, while 55% is farmed through tube wells and other sources. However, no water is available for the remaining 15%. The extent and spread of monsoon rain are declining over time, due to climate change. The summer monsoon comprises 60% of the total annual precipitation. Moreover, Pakistan has inadequate water storage facilities and aging water infrastructure, including its vast irrigation network, making it a water-stressed country.

Despite the growing amount of literature on climate change-caused decline in crop yield in Pakistan, the nature and extent of its economic effects remain largely unstudied. Moreover, research on the consequences of these agricultural impacts for human livelihoods is quite limited. The majority of existing research focuses on partial equilibrium analysis of the direct effects of climate change variables, such as temperature and precipitation, on crop yields and output. These studies suggest reduced crop yield and production, due to climate change. However, partial equilibrium analysis has three broad limitations.

First, these studies only emphasize crop output or revenue, and therefore, give an incomplete understanding of the implication of crop yield changes for human livelihood. Secondly, they overlook the importance of climate change with respect to income and expenditure of different types of households. Lastly, they overlook the inter-connections of different countries and their production systems that might influence the domestic price. Keeping in mind the inter-linkages of domestic and global economies, the effects of changing climate on agricultural production would not just be limited to crop yield, but would affect the whole economy. Agricultural output is consumed directly and indirectly as raw materials. Any change in crop production would affect the overall economy. Hence, the results of existing partial analysis studies do not provide complete guidance to policy-makers.

International institutions like World Bank, Food and Agriculture Organization and International Food Policy Research Institute have been emphasizing for a long time now towards the alarming rates of the anticipated population growth based on their long range population projections (Pinstrup and Andersen, 1999). On other hand, there is a difference of opinion on whether or not the world agriculture and food sector possesses substantial potential to feed future population. The traditionalists view growth in agricultural production through research and technology continuously reigning largely in the parts of the world' (Alexandratos, 1995).

Then are ecological economists who view the agricultural production in the context of biophysical limits on carrying capacity. The Neoclassical Economists tend to reject this focus on limits, arguing that technological progress in raising yields can extend global carrying capacity well beyond present levels and local or regional limits can be overcome through trade (Mitchell, 1995). Crosson and Anderson (1992) are more optimistic on cropland expansion, projecting about 25% expansion by 2030. But they too indicate the crucial role of yield increases, saying that "the majority of all future increases in crop production will have to come from higher output per hectare".

The Pakistan Case According to 2009 World Population datasheet, the population of Pakistan was 172.8 million in 2008 and is projected to be 228.9 million in 2025 and yet 250.2 million in 2050, making her the 5th populous country on the globe (DEPweb, 2009). The historical evidence proves that the food production in the country has increased almost 50 percent over the past 20 years. The rate at which agriculture has progressed encourages the belief that progress would continue without worrying much. However, the Agriculture sector in general and the crop sector in particular is deemed to be working far below its genuine potential, presently. In spite of 'so called' favorable conditions of soil, irrigation water and climate, agriculture in Pakistan suffers from under-utilizing of its potential resources, resulting in unnecessarily low yields per hectare and per unit of water consumed. Sandhu back in 1993 maintained that there was a considerable 'unachieved potential in wheat, 74%; paddy, 82%; maize 82%; sugarcane 86%; rapeseed, 77% and potato 73%, however, the country is still far from realizing the large potential yield that the well-irrigated and fertile soil from the Indus Irrigation System could produce'.

Another study of Pakistan's agriculture reported that country's food supply 'remains highly dependent on good harvests rather than on any institutionalized process of technical change and it is therefore, vulnerable to sharp downturns (Gizewski, Peter and Dixon 1996). Malik, 1973 very critically expressed that discrete analysis over time reveals that 'agricultural production in Pakistan is highly erratic; one good year is either preceded or followed by bad year(s)'. Ahmad (1993), Faruqee (1999) and Ali & Byerlee (2002), time and again, raised the concerns regarding Pakistan crop sector's potential to meet the challenge of providing food and fiber to its ever growing population.

Therefore the above literature suggests the in order to have a better yield the country like Pakistan should have to take certain measures which countries challenges like climate change and in order to combat such issues it needs to take effective steps for the improvement of yield of all crops in particular and the agriculture sector as a whole.

Conclusion

Based on the findings of this study, some key policy implications have emerged, e.g. to close the yield gap of major food crops, the limitations of water resources, land suitability and land input should be considered. More specifically, to increase food crop production and ensure food security, Pakistan needs to strictly protect its cropland resources, encourage the promotion of cultivation technology and enhance farmland quality. Accordingly, the farmland infrastructure should be strengthened for all major crops, and resource allocation should be optimized to increase grain yields.

The government of Pakistan should guarantee a fair-share public return to farmers to inspire their enthusiasm for growing crops and encourage them to efficiently utilize their land resources. However, the lack of disease-resistant, good quality, high yielding and widely adapted cultivars is the main reason for low production in the country. Hence, improvements in agricultural management and research and development for releasing high yield crop cultivars must be actively pursued.

Agricultural production needs to be increased substantially to keep pace with the growing demand for agricultural commodities. Current studies tend to determine the potential grain yields of major food crops on provincial and national bases reveal that the total potential production and the actual total grain production of Pakistan were 100,933 000 kg and 38,227 000 kg, respectively, with a production gap of 62,706 000 kg. The national exploitation rate of potential grain productivity was 0.38, which indicates that only 38% of the total attainable grain production has been achieved and that there is still considerable potential (62%) to improve current production levels. From the yield gap analysis, it is concluded that high actual yields are mainly concentrated in the southern part of the country; however, due to geographical topography, environment, soil and climatic conditions, there is some heterogeneity in the potential and actual yields across the country.

Regardless of the excellent soil and climatic conditions in Pakistan, the actual yields of the major food crops are much lower than their potential yields. Based on the above discussion, it is concluded that the yield gaps of the selected crops vary from crop to crop and from place to place. Several anthropogenic and biophysical constraints are responsible for the low yields in Pakistan. Due to rapid population increase and urbanization, agricultural lands, dense forests and water bodies have been depleted which, in turn, exert great pressure on agricultural production. Based on the findings of this study, some key policy implications have emerged, e.g. to close the yield gap of major food crops, the limitations of water resources, land suitability and land input should be considered. More specifically, to increase food crop production and ensure food security, Pakistan needs to strictly protect its cropland resources, encourage the promotion of cultivation technology and enhance farmland quality.

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