Pacific Science Review B: Humanities and Social Sciences 1 (2015) 145–158

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Pacific Science Review B: Humanities and Social Sciences

journal homepage: www.journals.elsevier.com/pacific-science-review-b-humanities-and-social-sciences/

Economic perspectives of major field crops of Pakistan: An empirical study

Abdul Rehman [a,*], Luan Jingdong [a], Babar Shahzad [b], Abbas Ali Chandio [c], Imran Hussain [d], Ghulam Nabi [e], Muhammad Shahid Iqbal [f]

[a] College of Economics and Management, Anhui Agricultural University, China
[b] School of Agronomy, Anhui Agricultural University, China
[c] College of Economics and Management, Sichuan Agricultural University, China
[d] Allama Iqbal Open University, Pakistan
[e] School of Public Affairs, University of Science and Technology of China, China
[f] School of Computer Science and Application Technology Anhui University, Hefei, China

A R T I C L E I N F O

Article history:
Received 20 August 2016
Accepted 8 September 2016
Available online 19 November 2016

Keywords:
Economy
GDP
Pesticides
Major crops
Water scarcity

A B S T R A C T

Agriculture is considered the backbone of Pakistan's economy, which relies heavily on its major crops. There are vast gaps between the acquired and actual output of produce, which suffers due to a lack of appropriate technology, use of inputs at improper times, unavailability of water and land use and inadequate education about insect pest control, which not only negatively affects the produce but also significantly reduces the amount of produce. Farmers mainly use synthetic chemicals for the control of insect pests, but these are used unwisely. To emphasize the major shortfalls and actual performance of major field crops, this study investigated the relationship between agricultural GDP and the output of major crops, including wheat, rice, sugarcane, maize and cotton, in Pakistan over a period of 65 years from 1950 to 2015. Time series data were collected from the Economic Survey of Pakistan (various publications). Crop data were analysed using the ordinary least square method and the Augmented Dickey Fuller (ADF) test, and the results were interpreted using Johansen's co-integration test. Our study finds that the output of wheat, rice and cotton has a positive and significant relationship with the agricultural GDP of Pakistan, while the output of sugarcane has a negative and non-significant relationship with the agricultural GDP of Pakistan. Therefore, this study recommends that the government of Pakistan should launch new funding programmes for the development of the agricultural sector.

1. Introduction

Agriculture is an important sector of Pakistan's economy. This sector directly supports the country's population and accounts for 26 percent of gross domestic product (GDP). The major agricultural crops include cotton, wheat, rice, sugarcane, fruits and vegetables. The irrigation system of Pakistan belongs to one of the world's largest systems to support agricultural production. There are two main seasons in Pakistan for production of crops: crops such as cotton, rice and sugarcane start in May and are harvested in November, whereas the wheat crop extends from November to April. A key urgent need to improve agricultural production is to use resources, mainly land and water, more efficiently. However, the change is mainly dependent on large landowners, who own 40 percent of arable land and control most of the irrigation systems, making it difficult to pass wide-ranging reforms. Pakistan is a net importer of agricultural products, with total annual imports of approximately 2 billion USD, including wheat, edible oils, pulses and food additives.

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 (Hazell,

* Corresponding author.
E-mail address: abdulrehman@ahau.edu.cn (A. Rehman).
Peer review under responsibility of Far Eastern Federal University, Kangnam University, Dalian University of Technology, Kokushikan University.

http://dx.doi.org/10.1016/j.psrb.2016.09.002
2405-8831/

2010). 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 ha was used for wheat production, which was 51 percent of the entire wheat area in Pakistan (Smale et al., 2002).

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, approximately 25 percent of exports is Pakistan's share. Rice exports are the second highest source of income in Pakistan. Rice grains fulfil 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). Rice is an important food for Pakistan. 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).

Cotton is another cash crop of Pakistan, and 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 labour force (FAO, 2012; GOP, 2012). According to current agricultural policy, the Pakistan Central Cotton Committee has aimed to increase the production of cotton from 40 percent to 60 percent (PCCC, 2008). However, some 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).

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, and previous research (Heisey and Edmeades, 1999) has shown that drought stress also causes grain yield damage when it occurs in the reproductive stage of the crop's life cycle.

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; Nazir et al., 2002).

2. Current scenario of major field crops of Pakistan

2.1. Wheat

Wheat is an important cereal crop for many countries, where it is consumed as a staple food. It is an admitted fact that nothing is more important than the needs of human beings. Sustainability and reliability in food production are very important for sustainable crop production. For wheat production, water supply and energy are important and will continue to constitute an important foundation to ensure the sustainability of agriculture and food production reliability. However, water and energy preservation are two key issues for researchers to decrease the costs of these two commodities in such a manner that production will not be hampered. In the 1980s, Pakistan experienced a golden era of water management in the construction of the canal irrigation system, which was developed at the same time; however, the results of different droughts reduced what the system could achieve. The country could only barely emerge from the eye-opening shock of water scarcity that persisted for almost three years from 1999 to 2002. Water scarcity caused over-use of ground water by pumping out this water, consuming an enormous amount of available energy, while the country was already facing a problem with this commodity (Pakistan, 2008–09).

Moreover, it has been reported that the availability of water for agriculture is expected to decrease from 72 percent to 62 percent in the period from 1995 to 2020, and globally, a decrease from 87 percent to 73 percent in developing countries was also estimated (Khan et al., 2006). Because Pakistan is an agricultural country, water scarcity in agriculture will have disadvantageous impacts on its economics because agriculture directly subsidizes its GDP, and more than 40 percent of labour is directly or indirectly engaged in this sector (Pakistan, 2008–09). In Pakistan, traditional crops, such as wheat, are planted on a flat basin that is directly flooded with water for irrigation. There are enormous water losses with this type of irrigation. Evaporation and deep percolation losses also cause a severe shortages to crops related to overexploitation of groundwater, encouraging a search for alternative methods of water application to crops, for example, raised bed (RB) technology, to meet water demands.

There is a serious challenge for agriculturists to meet the feeding requirements of nine billion people by the middle of the 21st century (FAO, 2009). To produce more food from less water in arid and semi-arid areas is a challenge for today's agriculture (Shideed, 2011). Water shortage and scarcity cause degradation of land due to rainfed agriculture (Suleimenov et al., 2011) and lower food production, particularly in the agricultural and semi-agricultural zones of Africa (Fraiture et al., 2010). Approximately 80 percent of the world's agriculture comprises rain-fed land, which produces 80 percent of the food globally (Falkenmark et al., 2001; Valipour, 2013).

In North Africa and West Asia, 95 percent of land is rain-fed, and approximately 40 percent of the land in Uzbekistan has been used due to water shortages, causing despoiled fields (Shaumarov and Birner, 2013; Zakaria et al., 2013). Wheat is an important crop in Pakistan due to its widespread use as food (Iqtidar et al., 2006). In Pakistan, 6.35 million hectares of land are irrigated with canal water, 12.53 million hectares are cultivated through tube wells, and for the remaining 3.59 million hectares, no water is available, for a total 22.45 of million hectares (GOP, 2012). Limited water results in susceptibility to water scarcity conditions, causing wheat biomass to reduce wheat crops (Oweis and Hachum, 2004; Tavakkoli and Oweis, 2004; Xie et al., 2005). Poor and sparsely distributed rainfall in arid regions of Pakistan further aggravates this situation. Losses ranging from very low yields or even complete loss under severe water stress in wheat crops have been well documented (Oweis, 1997). Harvesting and utilization of rain water have been successfully used in many arid regions, using runoff water from the catchment area and delivering it to the collection acreage (Qiang et al., 2006; Short and Lantzke, 2006). Rain water efficiency can be improved with appropriate water harvesting techniques, such as micro-watersheds (Rogelio et al., 2006; Zakaria et al., 2012). Using this technique can increase the capacity of water per unit of crop area and can also increase productivity (Oweis and Hachum, 2003; Ramotra and Giakwad, 2012). The area under wheat cultivation per 1000 ha and the area yield in kilograms per hectares in Pakistan are shown in Figs. 1 and 2, respectively.

2.2. Rice

Rice is an important crop for many countries, and its culture extends from the humid tropics to northeast China and southeast Australia, from sea level to an altitude of more than 2500 m in the moderate regions of Nepal and Bhutan. Although most rice is cultivated in Asia, there are many rice cultivation areas in Oceania and Europe. Due to its wide geographical distribution, rice is cultivated in many climates and on a wide range of soils, with huge differences in soil properties. Early studies emphasized flooded rice production in Asia due to the characterization of rice soils (IRRI, 1978, 1985; Kawaguchi and Kyuma, 1977; Moormann and Breemen, 1978). However, most studies have focused on the specific characteristics of waterlogged soil treatment (Banta and Mandoza, 1984; Kirk, 2004) (Kögel-Knabner et al., 2010; Ladha et al., 1992; Ponnamperuma, 1972; Wassmann et al., 2000), and recent studies have emphasized that the spatial representation and distribution of rice soil are rare.

Consequently, comparable quantitative data about paddy soil quality areas and rice production systems are unavailable, and important issues related to soil quality are usually treated only qualitatively and can usually be answered by local experts. To better understand the spatial representation of soil quality and barriers could serve several purposes. To evaluate the target and focus on agricultural research, spatial information about environmental constraints on crop production can be used (Hijmans et al., 2003), assisted by communication technologies (Singh and Singh, 2010). The spatial distribution and properties of soil, climate, hydrology-related, and abiotic factors emphasize the importance of the target, which can help with specific features, such as submergence tolerance (Xu et al., 2006), tolerance of better rice varieties (Huang et al., 2010), phosphorus deficiency tolerance (Gamuyao et al., 2012) and water stress tolerance (Verulkar et al., 2010). Similarly, this type of information can be used to improve the study and dissemination of management options and issues related to a particular soil. The sustainability of the conventional rice system is susceptible to water and deteriorating energy resources. For this reason, resource-saving technologies (RCTs) are being developed and disseminated to promote global rice production (CGIAR, 2010; IRRI, 2010).

Another rice production technology has shown great potential to improve resource utilization technology in non-banks and non-

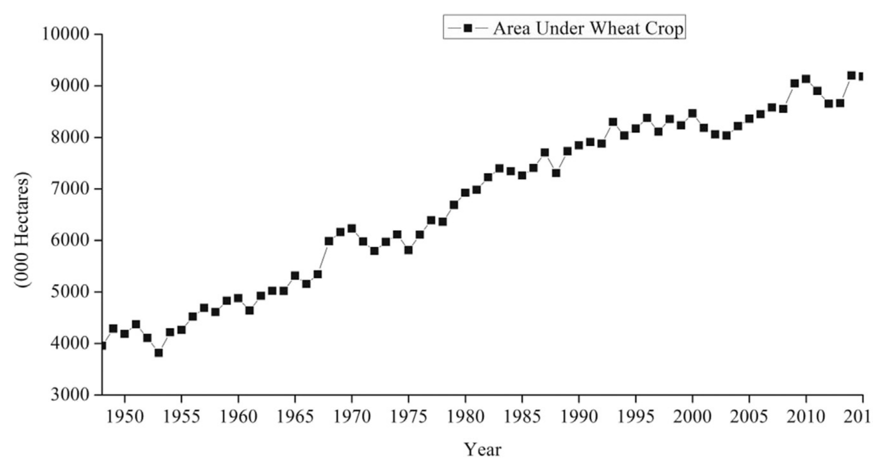

Fig. 1. Area under wheat cultivation, 1948–2015.

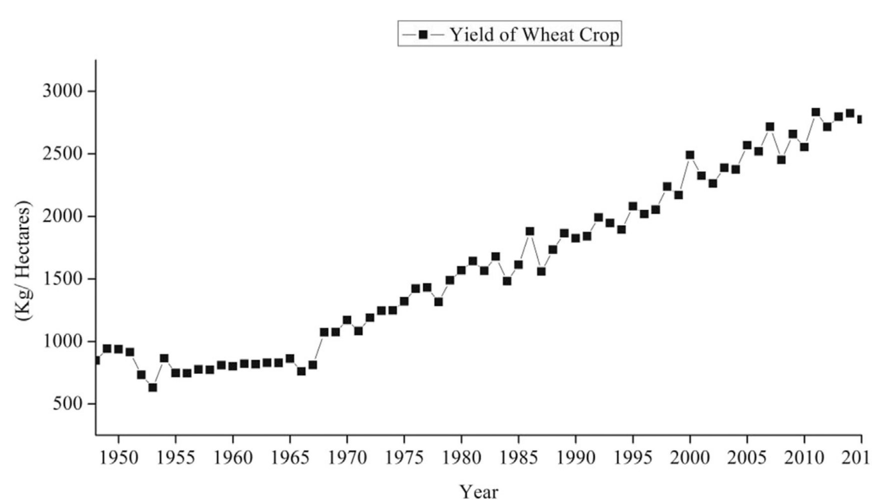

Fig. 2. Yield of wheat crop in kg/ha, 1948–2015.

flooded areas, similar to other crops, such as unsaturated soils under wheat and maize and drought sowing of upland rice. Aerobic rice varieties are developed by crosses between traditional lowland and upland varieties that combine some of the yield-potential traits of lowland varieties with adaptation to aerobic soils (Atlin et al., 2006). Aerobic rice systems (ARS) have been established in temperate environments, and work is under way to improve these systems in tropical and subtropical regions to improve the incomes of local farmers and regional and national food security (Maclean et al., 2002; Prasad and Donald, 2011).

Another technology of rice cultivation is paddy rice, which is usually grown by transplanting 25- to 35-day-old seedlings in well prepared puddled soils to control purification, weed growth, and infestation, and it requires an enormous amount of fresh water for its proper growth. Growing paddy rice in Pakistan is a serious challenge for food security, while limited water reservoirs and increasing population are other challenges (Briscoe and Qamar, 2009). According to an estimate, during the fiscal year 2011–12 (1 July to 30 June), the availability of water from canal irrigation was approximately 10 percent less than the long-term average systemic water use of 128 billion m^3 (GOP, 2012). The ground water table has decreased by a factor of nearly 0.3 m per year (Hussain, 2002), and over the years, it has decreased due to groundwater exploitation and utilization of more than 7 m (Kahlown et al., 2007). Increases in fuel prices have also resulted in high charges for pumping ground water, resulting in decreased net economic profits. Shortage of labour is another factor during growth periods of rice that hampers its production and causes delays in transferring seedlings because manual evacuating and transplanting of nurseries are important tasks for rice cultivation. The limited labour force mainly consists of unskilled and contractual women and teenagers, with a lack of quality assurance, uneven plantations and economic densities much lower than agronomically optimal (Baloch et al., 2005; Chaudhary et al., 2001; Farooq et al., 2011).

More recently, several techniques have been introduced for rice cultivation, such as alternative wetting-drying, direct seeding, mechanized systems of rice amplification, and aerobic rice systems, and these systems have been verified and up-scaled in the provinces of Punjab and Sindh by the Pakistan Research Council (PARC), in collaboration with national and international research organizations (IRRI, 2010; Sharif, 2011). For a brief discussion of these technologies and systems, we refer to Bouman et al. (2007). For instance, we are absorbed in the performance of aerobic rice systems, in which, as an alternative to the transplanting of seedlings, seeds are directly sown in the field. This system is well suited for those areas where there is a shortage of labour, and it also reduces the unit area cost (Pandey et al., 2002; Pandey and Velasco, 2005). Furthermore, there is a wide range of chemicals for weed control, which they also decreases the labour constraints for weeding during the season (Farooq et al., 2011). Irrigation requirements are fulfilled when there is a need to provide water to fields when soil water drops to less than a critical level. The overall performance of aerobic rice and directly seeded rice can be a more profitable and environmentally maintainable production system. For these reasons, aerobic rice systems could be an attractive alternative technology system in water-scarce environments (Bouman et al., 2007; Bouman et al., 2005).

According to a report published by FAO (2000), approximately 40 percent of all food is produced through irrigated agriculture, which consumes approximately 69 percent of all fresh water resources. Furthermore, estimations of world population growth predict increased demands for cereals, as well as rice and wheat, by 1.27 percent annually between 2000 and 2025 (Rosegrant and Cai, 2000). To achieve this projected food demand, there should be an increase of 17 percent in fresh water resources for irrigated agriculture (Seregeldin, 1999). To fulfil the requirements of the increasing population, there is pressure on the agricultural sector to produce higher yields in agricultural and semi-agricultural countries, where population growth is also high and the availability of fresh water is low, further intensifying lower consumption of water to produce more for an increasing population. This trend drives the bulk production of cereals, especially rice and wheat, using inferior amounts of irrigation water. Pakistan is expected to suffer such a scarcity of irrigated water in the near future. In Pakistan, farmers generally practice open flooded systems to irrigate fields in bundled units, resulting in poor water uniformity, long irrigation events, and over-irrigation (Kahlown and Kemper, 2004).

There is a trend towards relying on rice crops requiring standing water during the growing season to exploit the yields, and this type of practice leads to poor water use effectiveness. Many studies within Pakistan have revealed that 13 cm–18 cm of water is applied for irrigation, which is considerably more than the consumptive use between two irrigation events, which is for instance, approximately 8 cm (Kahlown et al., 2001). Additionally, irrigation efficiencies on farms range between 23 percent and 70 percent (Clyma and Ashraf, 1975; Kahlown et al., 1998; Kijne and Kuper, 1995). Furthermore, using a pressurized irrigation method, the planting of rice and wheat has been performed in different countries (Spanu et al., 1996). Sprinkler irrigation, such as with portable rain guns, can be used to apply a depth of water, and with the prevailing climatic conditions of the Indian subcontinent, sprinklers have improved farm irrigation efficiency by up to 80 percent (Sharma, 1984). The area for rice crops per 1000 ha and the yield in kilograms per hectares in Pakistan are shown in Figs. 3 and 4.

2.3. Cotton

Cotton is an important cash crop grown in Pakistan, and it contributes substantially to the national economy of Pakistan and is a key source of livelihood for rural people (Pakistan, 2012–13). It is widely grown in hot and humid areas, where there are high pest hazards because some insects are especially deleterious to the yield and quality of cotton. There are many requirements for high yield of cotton, such as high input, fertilizers, chemicals for pest control, highly drained soil, and water, and their utilization deteriorates the environment in different ways (Shafiq and Rehman, 2000). The major impacts of high input result in greenhouse gas emissions and water pollution due to leaching (IPCC, 2006). In Pakistan, freshwater bodies are being contaminated through runoff and the leaching of nitrates from agricultural land (Azizullah et al., 2011), and similarly, overuse and misuse of chemical pesticides also have deleterious impacts on crops and animals as well (Tariq et al., 2007). To obtain high yields, mechanization has also intensified the use of non-renewable energy. Farm management practices and the chemical and physical properties of the agroecosystem and soil greatly influence the magnitude of environmental hazards, and resource use in different forms and their effects vary with these practices (Choudhury and Kennedy, 2005). Furthermore, intensive input use, as a form of insurance for cotton yield and quality, incurs high production costs. Both environmental hazards and the high costs of cotton production challenge its sustainability and farmers' incomes in Pakistan; therefore, analysing and quantifying joint environmental impacts and the economic performance of cotton production are necessary. The question remains regarding how environmental impacts can be reduced while farmer income is sustained. The issue underlying this research is the trade-off among input use, environmental impact and economic performance in the cotton-growing regions of Pakistan.

Cultivation of cotton (*Gossypium hirsutum* L.) is a highly extensive type of farming that requires excessive utilization of resources

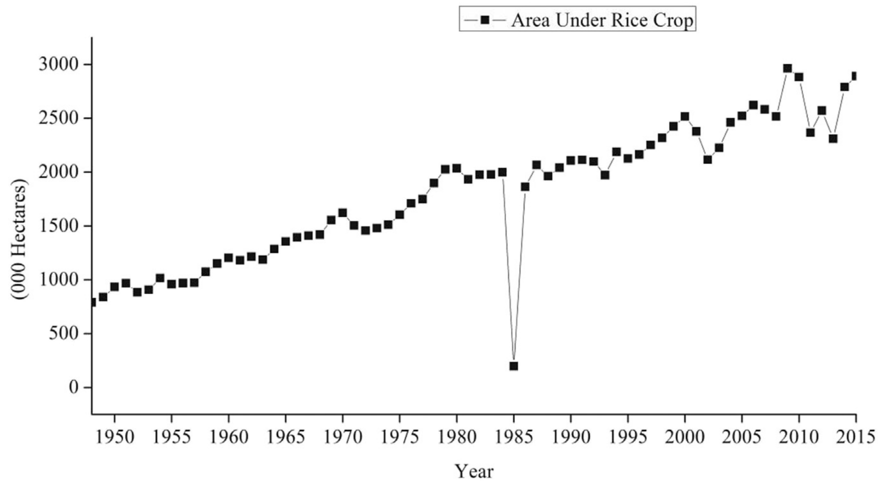

Fig. 3. Area under rice crops, 1948–2015.

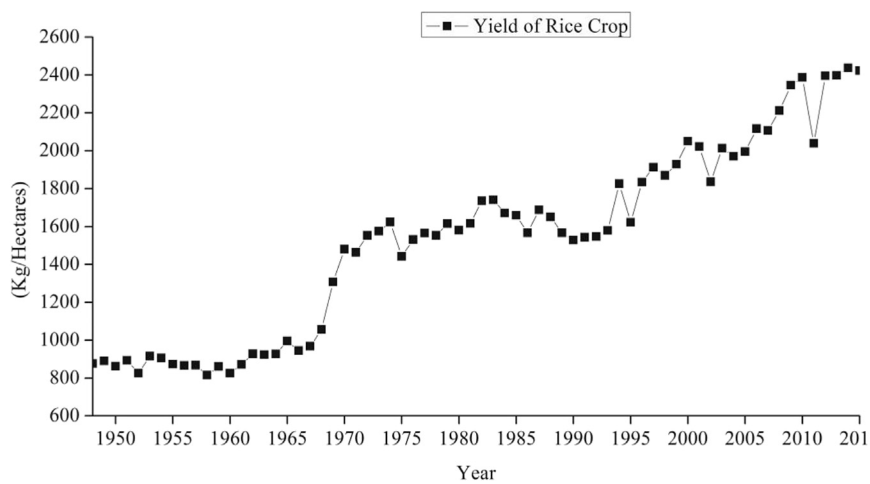

Fig. 4. Yield of rice crop in kg/ha, 1948–2015.

to protect the crop from insect pests, and synthetic chemicals are used extensively for better crop growth (Deguine et al., 2008; Hashemi and Damalas, 2011). There are many factors responsible for low cotton yield, but insects are ranked at the top of the biotic agents that not only deteriorate the quality of cotton produce but also reduce the yield. Farmers cannot afford highly protective measures due to small land holdings in almost all of the developing countries, and their extensive use leads to environmental pollution (Fitt, 2000). Another important aspect of cotton cultivation is plant pathogens, which are also regarded a serious threat to some areas, but their importance is less than that of other factors, such as inputs and agrochemicals (Oerke, 2006). Weeds are the second most important biotic agent posing a threat to cotton yield because they interfere with nutrient use and space, and they affect cotton while creating competition. Although there has been improvement in controlling these pathogens through chemical control, there has been large harvest loss, reaching almost 30 percent. Potential losses through non-utilization of inputs and weeds account altogether for 40 percent and 9 percent, respectively, of total losses being caused by pathogens and viruses (Oerke, 2006). Although large amounts of synthetic chemicals are used in cotton farming, losses account for almost 29 percent despite the use of pest control measures.

Crop protection has increased with increased use of synthetic chemicals and fertilizers in cotton crops, resulting in an overall increase in the yield of cotton crops (Damalas, 2009; Damalas and Eleftherohorinos, 2011). Today, agricultural productivity depends upon the utilization of chemicals; indeed, it is a well-known and extensive method for integrated pest management, and therefore, it is an integral part of agricultural systems. Synthetic chemicals have helped farmers to manage common pests easily and effectively that would otherwise pose a serious threat of reduced crop yield. In contrast, these chemical inputs in the agricultural systems not only create serious non-negotiable threats to the public but they also deteriorate the value of water and land environments (Carvalho, 2006; Maroni et al., 2006; Tilman et al., 2002; Werf, 1996). Moreover, another major concern regarding food commodities is the ingestion of food stuffs and water that are contaminated by these pesticide residues (Carvalho, 2006). Therefore, risks regarding the public and increasing ecological pollution posed by these pesticides have increased continuously, thus increasing resistance to their use (Atreya, 2008; Fantke et al., 2012; Pimental, 2005; Soares and Porto, 2009). Although there has been great improvement in the technical development of application equipment, which has enabled farmers to use chemicals more precisely, this professional use has not yet been transferred to the everyday technology that is used in many emerging nations.

At the same time, agricultural production can suffer from significant, negative effects due to damage to labour (Ajayi, 2000). This type of negative outcome can be evident in the of form lower production of farm due to less availability of labour for farms, which can decrease the income of labour because of lower outcomes or may reduce the free time available for the household because of time needed to attend to sick workers, or it can increase the workload of healthy workers. Furthermore, the measurement of health costs caused by the use of pesticides helps policy developers to determine the deleterious results of pesticide use on the overall reduction in terms of morbid effects on workers. Kishi et al. (1995) documented the relationship between the severity of health impacts on personal hygiene and the utilization of chemicals; furthermore, they stated that the associations between health dangers and exposure to pesticides are pesticide dependent, but in contrast, lack of data has further intensified the situation, and the existing data often disagree about the degree of acceptance of this hypothesis due to unreliable consequences and issues about some methodologies that must be amended. As a consequence, decreased pesticide use has been perceived by many people as an approach to improve the health status of people in rural areas.

There is a dire need to propose some effectual well-being strategies to decrease the effects of pesticides on the rural population, which could further exploit the development of monetary assessment of health costs that are caused by pesticide usage. Nonetheless, the assessment should focus on both market and non-market costs. In rural areas, smallholders are reluctant, they are not concerned with health-related expenditures encountered to cure illnesses resulting from direct exposure to insecticides, and they ignore imperceptible costs, such as anxiety, pain and suffering, as a usual part of their work. Moreover, the health impacts of pesticide use have traditionally been neglected from the investigations of incomes in farming, and the reliability of data and lack of appropriate methodologies are serious causes of health impacts due to insecticide usage that have usually been ignored in investigations of earnings in rural research and the estimation of precise farming strategies (Atreya, 2005). In contrast, there is no direct noticeable value prevailing for the decrease in insecticide health concerns, and non-market assessment methodologies to monetize individual preferences should be applied. These techniques are truly helpful, and they assist in such a manner that values are reflected in the individual's willingness to pay (WTP) to decrease human health hazards. Therefore, personal preferences regarding health concerns are related to the reimbursement of risks. Then and now, the health assessments of costs by insecticides have absorbed market modules, generally estimating the costs of sickness (Ajayi, 2000).

Many factors are responsible for pesticide use due to people's health concern because opinions about insecticide hazards affect farmers' overall behaviours regarding their usage (Damalas and Eleftherohorinos, 2011; Dasgupta et al., 2005; Hashemi et al., 2012; Liu and Huang, 2013). Therefore, there must be basic education for pesticide handling and safe use, as well as uninterrupted emphasis on basic safety measures for pesticide use, which should be considered and which are essential to change the wrong behaviours of growers that can be dangerous to their health (Damalas et al., 2006a; Damalas et al., 2006b). In contrast, respondents' socio-geographic features are significantly important with regard to health hazards and perceptions and WTP attitudes (Huang, 1993; Sjoberg, 2000).

Use of pesticides is very important for pest management in cotton, and it mostly relies on proper use of synthetic chemicals. However, there are many differences from the proper application of chemicals during the crop cycle because many workers in the field do not apply pesticides according to crop needs, and they do not even know the basic components of farming and insect pest control (Khan et al., 2015; Midega et al., 2012; Ochou et al., 1998; Sinzogan et al., 2004). Furthermore, in developing countries, due to a lack of proper education, farmers are unable to apply pesticides, even to cotton, to control the insect pests, and they are unaware of the basic concepts of integrated pest management (IPM) (Arshad et al., 2009; Yang et al., 2005). One of the factors affecting pesticide use in practice is farmers' knowledge of pest management. Much of the literature has revealed that due to a lack of proper information about pest management, pesticide use by farmers was strongly linked to extensive pesticide usage (Chen et al., 2013; Khan et al., 2015). A clear inclination was found towards pesticide overuse among farmers in the Punjab province, but there was a declining tendency after proper education about integrated pest management (IPM) (Khan and Damalas, 2015). Similarly, many workers in developing countries are unable to follow the SOPs during the application of pesticides, and they do not even know how to utilize proper methods in pest control, compared with developed countries, where there is proper education about how to control pests in cotton (Midega et al., 2012).

In Pakistan, cultivation of cotton has relied chiefly on synthetic chemicals with farmers heavily dependent upon the synthetic pesticides for years; finally, it has intensified the tragic situation (Iqbal et al., 1997; Jabbar and Mallick, 1994; Tariq et al., 2007). To protect production from insect pests and pathogens and to boost agricultural productivity in terms of both magnitude and the value of the produce, farmers should exploit proper use of chemicals globally because their dependence on toxic chemicals is a threat to humans as well (Damalas, 2009; Damalas and Eleftherohorinos, 2011; Iqbal et al., 1997; Tariq et al., 2007). Consequently, it is a dire need to educate the public properly about cotton crops and related issues, such as insect pests and pathogen control. In addition, farmers must continue to seek new practices and methodologies for the control of these disastrous pests that can incur enormous costs to the product and that have always been a challenge for farmers to obtain good produce in terms of quantity and quality.

It has been noted that there are many hurdles if we want to apply such measures and approaches for farmers; furthermore, inadequate information and knowledge about the technology constitute another potent obstacle to adopting the technology (Damalas et al., 2006a; Hashemi and Damalas, 2011; Hashemi et al., 2012). Programmes were found to have failed due to a lack of adequate knowledge of farmers about pesticide use. However, requirements to understand farmers' perception and knowledge should be recognized that could be served for better adaptation of technology regarding integrated pest management (Hashemi and Damalas, 2011).

Hence, it is believed that farmers' socioeconomic situations and their perceptions of and knowledge about the current status of insect pest menace is of great importance for establishing pest management techniques. Identification of farmers' prerequisites for information and finding the proper way to afford them are continuous trials. Different farmers' surveys are always very important and helpful because they are useful for identifying the problem and its solution, testing a research hypothesis, establishing new strategies, and assessing the efficiency of developments and new interventions. For these purposes, the objective of this study is to identify potential points for interventions in the improvement of pest control strategies for cotton pests, based on the needs of small-scale farmers in the province of Punjab. The area under cotton crops per 1000 ha and area yield in kilograms per hectare of Pakistan are shown in Figs. 5 and 6, respectively.

2.4. Maize

Inorganic fertilizers play an important role in producing high yields worldwide, and nitrogen fertilizer (N) is applied in bulk

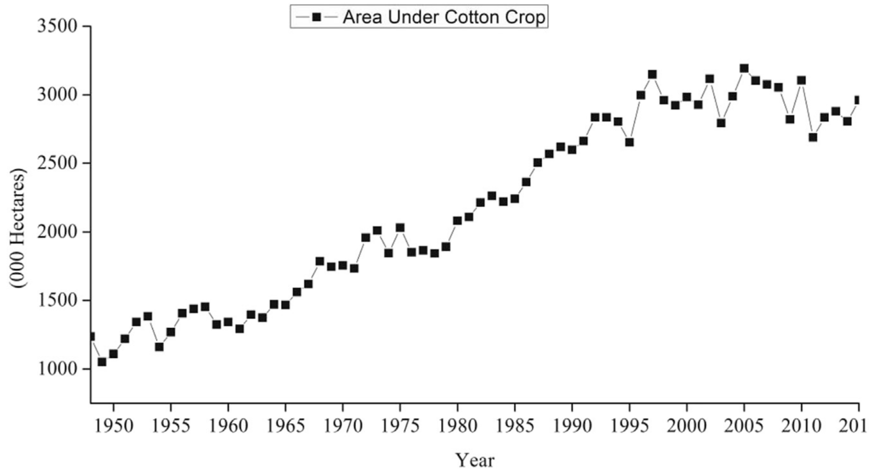

Fig. 5. Area under cotton crops, 1948–2015.

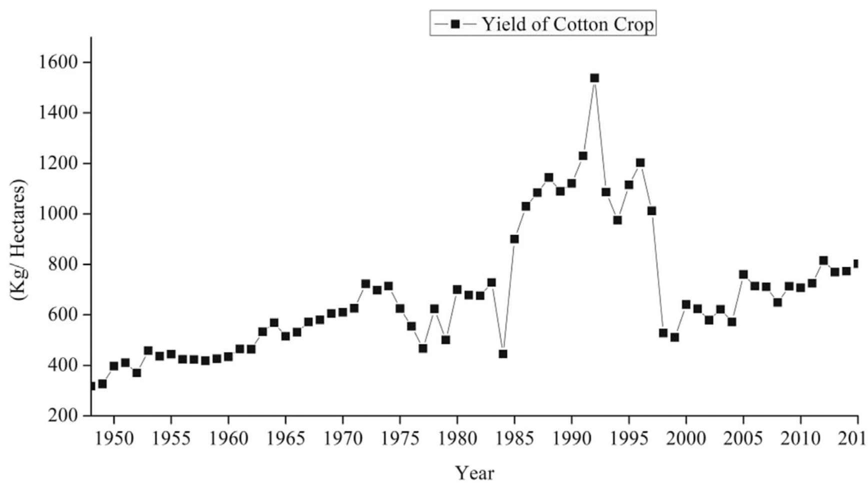

Fig. 6. Yield of cotton crop in kg/ha, 1948–2015.

quantities because it is required in large proportions during the plant life cycle. Nitrogen application through chemical fertilizers is the main and major source of N input in the crop cultivation system worldwide. According to estimations, 50 percent of the human population currently depends on N fertilizer for food production, while 60 percent of nitrogen is utilized in producing three major cereal crops: rice, maize and wheat (Ladha et al., 2005). Unfortunately, it is also evident that applied nitrogen fertilizer is not efficiently utilized by plants and is lost through volatilization and leaching, causing serious threats to water and terrestrial environments, while recovery of this nitrogen only accounts for 50 percent of applied nitrogen, and in cereals, nitrogen recovery accounts for only 40 percent globally (Fageria and Baligar, 2005; Ruan and Johnson, 1999; Ruan et al., 2002). Fageria and Baligar (2005) reported that low recovery of nitrogen fertilizer was due to its volatile properties, which are associated with leaching, denitrification and soil erosion. Additionally, the dynamic nature of nitrogen, its mobility in plants, and its transformation processes in soil make it an element that is not efficiently utilized. Furthermore, Ruan and Johnson (1999) estimated that 67 percent of total applied nitrogen was lost, worth $15.9 billion annually, and even only a 1 percent increase in nitrogen recovery could result in global savings of $234 million (Glass, 2003). Therefore, nitrogen use efficiency (NUE) of applied nitrogen fertilizer is a real concern to researchers engaged in N cycling and transformation. To improve nitrogen efficiency in crop production, N management strategies should consider improved fertilizer efficiencies, along with soil and crop management practices. Among these management practices, adequate rates and appropriate uses of fertilizer and the timing of fertilizer application during the crop growth cycle play important roles (Abbasi et al., 2012; Fageria et al., 2006). Such strategies not only boost yield but also reduce the costs of production and environmental hazards.

Mineral nutrition plays an important role in crop production; among plant nutrients, nitrogen is of great importance to crop productivity (Ahmad, 1998, 2000; Zapata and Cleenput, 1986), and nitrogen deficiency is one of the potential reasons for limited yield of cereals (McDonald, 1989; Shah et al., 2003). Continuous cereal cropping systems cause nitrogen deficiency through the decomposition of inorganic fertilizer, and this deficiency should be overcome through supplementation from other sources (Herridge and Doyle, 1988; McDonald, 1992; Strong et al., 1986).

Adequate nitrogen fertilizer is applied as a chemical fertilizer in most developed countries. However, in developing countries such as Pakistan, it is not possible due to the high price of fertilizer, low farm incomes and lesser availability of credit facilities to farmers; hence, yield is hampered due to these factors. As a consequence, either farmers use the available organic sources, or the crop remains unfertilized due to limited sources (Herridge et al., 1995). In contrast to developed countries, farmers in developing countries, especially in Pakistan, are indispensably inclined towards using commercial fertilizer to satisfy the required level of plant mineral nutrition. Over the last few years, fertilizer prices in most developing countries have reached unprecedented highs, whilst supply has been limited when sowing time has approached (Shah et al., 1995), resulting in failure to achieve target yields and national production potentials.

In continuous cereal cropping systems, there must be the inclusion of a legume crop to overcome nitrogen deficiency, and these crops can play a vital role in maintaining soil fertility, as well as sustaining crop production. Leguminous crops have the ability to transform atmospheric nitrogen into organic nitrogen through their modulated roots; hence, they have proved to be a valuable source of organic N (Giller, 2001; Munyinda et al., 1988; Peoples and Craswell, 1992).

Increased interest has been shown by farmers and researchers in crop rotation and management of crop residues as valuable management tools. Research studies have clearly revealed that the appropriate addition of organic materials is most important for maintaining tilth, soil fertility, and agricultural productivity and for controlling wind and water erosion by preventing nutrient losses due to run-off and leaching (Bukert et al., 2000; Lal, 1980; Maurya, 1981). Despite these advantages, farmers prefer to remove crop stubbles from the field and use them as fuel and fodder for their livestock or as building materials. In contrast to sustainable farming system, farmers use these stubbles for mulching and to improve the soil's physical and chemical properties and, hence, to increase soil organic matter. Soil organic matter plays a vital role in replenishing the soil's chemical and physical properties, and it is necessary to include legumes in crop rotation and to retain crop residues. The area under maize crops per 1000 ha and the area yield in kilograms per hectare in Pakistan are shown in Figs. 7 and 8, respectively.

2.5. Sugarcane

Sugarcane is widely grown in the tropical and subtropical regions of the world, with high economic importance. According to an estimation in 2014, sugarcane was planted on an area of 27 million hectares in more than 100 countries worldwide (FAOSTAT, 2015). Globally, Brazil ranked first in terms of sugarcane production, with 39 percent of total world sugarcane production, and India ranked second with 19 percent overall, followed in order by China, Thailand and Pakistan with production rates of 7, 5 and 4 percent, respectively (FAOSTAT, 2015). So far, in the sugar industry, sugar is usually utilized for its sucrose content, which is further used in the

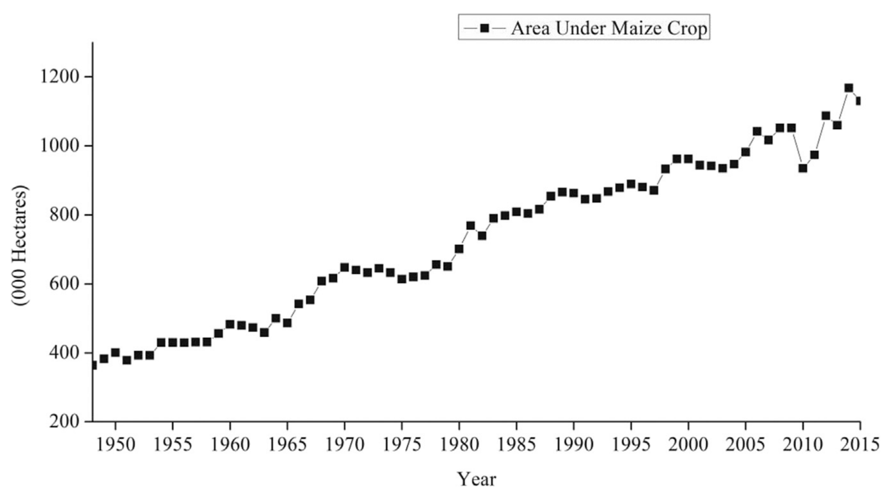

Fig. 7. Area under maize crops, 1948–2015.

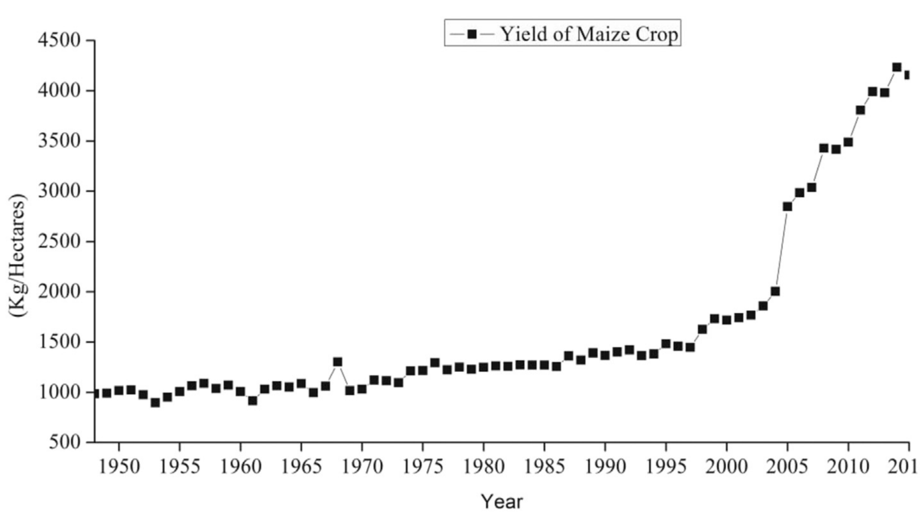

Fig. 8. Yield of maize crops in kg/ha, 1948–2015.

industry as a sweetener, and the remaining biomass residue (bagasse) after extraction of sucrose is consumed as a fuel to provide steam and electricity to run sugar mills. However, there has been increasing awareness about its co-products, such as cane trash, molasses, bagasse and filter cake, which are today used in many industries, and many refined products, e.g., bioethanol and electricity, as well as chemicals, including a variety of polymers (Dias et al., 2013).

India has secured its position as the largest producer, consumer and trader of sugarcane products. Its production has been paid great attention by society and government due to its abundance. Sugarcane (*Saccharum officinarum* L.) is believed to be the most important traditional and commercial crop of industrial importance worldwide due to its strategic and commercial application in almost all industries. The importance of the sugarcane industry is increased in recent years due to its economic impact on sustainable energy production. Sugarcane industry provides raw material for the second agro-based industry after textiles, and it is a base for all major sweeteners produced in the country. Furthermore, unprocessed sugarcane is consumed as a human food and animal feed in Brazil, India and Cuba, and these countries are the world's leading sugarcane producers, constituting more half of the total sugarcane production in the world (Girei and Giroh, 2012).

In rural areas, sugarcane cultivation remains as an important segment of socioeconomic development because it produces higher incomes and provides employment opportunities to more than half a million people globally. Sugarcane production and prediction both have direct and indirect impacts on national and international economies, and sugarcane plays a vital role in the management of food (Hayes and Decker, 1996). Assessment of its reduced production, which is caused by natural disasters, such as insect-pest infestation or droughts, could be critical for those countries where the economy is completely dependent on sugarcane production. Similarly, early detection and management of problems associated with crop harvest can help to boost the yield and subsequent profits.

Early predictions about crop yield can be useful globally and regionally, offering important information for policy makers. This information can also help farmers at the field level to make quick decisions about upcoming circumstances, for instance, the choice of alternative crops or whether to stop a crop from growing further at all or in an early stage. Barnett and Thompson (1982) used some meteorological data based on precipitation and temperature to forecast wheat yield. Similarly, Parthasarathy et al. (1988) developed some equations to forecast yield using regression models. At the same time, Deressa et al. (2005) applied a Richardian cross-section using a regression model and proved that climate change has serious connections with sugarcane productivity. In that study, climatic variables such as minimum and maximum temperature were not considered. In another study, it was reported that high fertilizer application had greater impacts on climatic variation and environmental damage (Ranuzzi and Srivastava, 2012). In precision agriculture, principles of artificial intelligence and soft computing techniques have been utilized for spatial analysis and crop management (Drummond et al., 2003; Huang et al., 2010); in particular, ANN analysis has been utilized in precision agriculture to compute data relative to spatial analysis and crop management (Drummond et al., 2003; Irmak et al., 2006).

In another study, the yield of sugarcane alone and in rotation with potatoes (*Solanum tuberosum* cv. Kufri Bahar) was increased, and net income was also significant in intercropping systems (Imam et al., 1990). Control of insects and pests, such as diseases, insects and weeds, in sugarcane rotation has also been studied (Berry et al., 2009; Chen et al., 2011; Li et al., 2009); however, there has thus far been a lack of information assessing the interspecific competition in sugarcane intercropping system. One important factor in intercropping systems is competition, which plays a direct role in determining the yield of crops (Caballero et al., 1995; Li et al., 2011). Vandermeer (1990) confirmed that when intra-species competition in an intercropping system is greater than inter-species competition, an increase in yield could be seen in these cropping systems.

Several major advantages can be achieved in cereal-legume intercropping systems that increase yield and land use efficiency (Ghosh, 2004), as well as efficiency in the utilization of natural resources, such as water, light and nutrients (Harris et al., 1987; Xu et al., 2008). It can also add up in controlling insect pests and diseases (Chen et al., 2011). Furthermore, cereal-legume intercropping systems have emerged as popular cropping systems worldwide (Eskanddari, 2012; Jensen, 1996). The area under cotton crops per 1000 ha and the area yield in kilograms per hectare in Pakistan are shown in Fig. 9 and 10, respectively.

3. Materials and methods

To examine the relationship between the agricultural GDP and the outputs of major crops, annual time series data from 1950 to

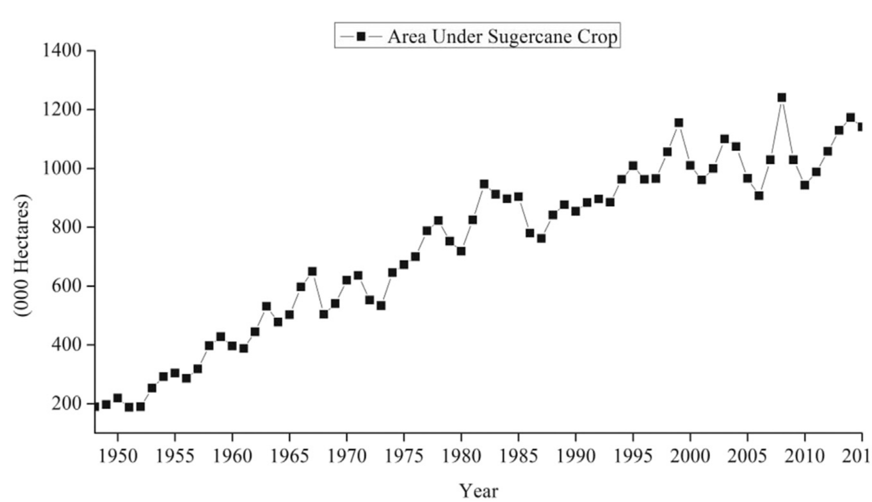

Fig. 9. Area under sugarcane crops, 1948–2015.

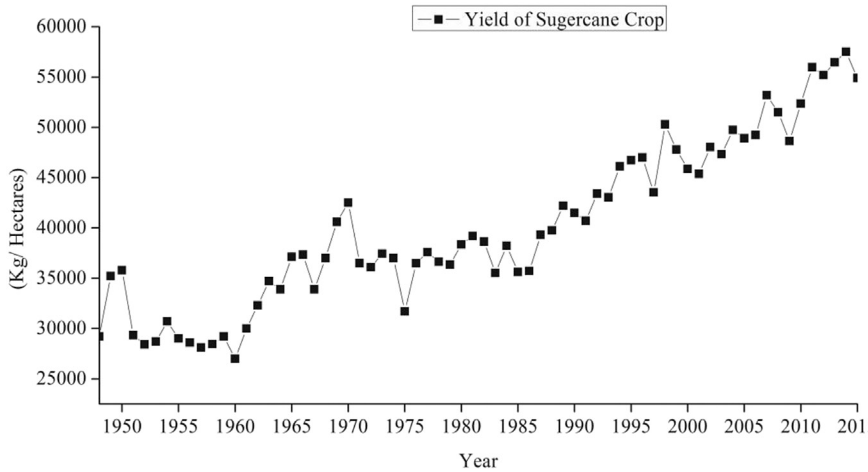

Fig. 10. Yield of sugarcane crop in kg/ha, 1948–2015.

2015 were used. The data were collected from the Economic Survey of Pakistan (various statistical supplements), Pakistan Statistical Year Books, Government Publications and the Federal Bureau of Statistics. The variables used in this study are agricultural GSP in millions of rupees, output of cotton in thousands of tonnes, output of maize in thousands of tonnes, output of rice in thousands of tonnes, output of sugarcane in thousands of tonnes and output of wheat in thousands of tonnes.

3.1. Model specification

To analyse the relationship between the agricultural GDP and the outputs of major crops, the following model estimated is specified as:

$$ln(AGRGDP) = \beta_0 + \beta_1 ln(OPCOTTON) + \beta_2 ln(OPMAIZE) + \beta_3 ln(OPRICE) + \beta_4 ln(OPSUG) + \beta_5 ln(OPWHEAT) + \mu \ldots \quad (1)$$

where

Ln *(AGRGDP)* = Agricultural Gross Domestic Product per year in (million rupees)
Ln (OPCOTTON) = Output of Cotton in (000, tones)
Ln (OPMAIZE) = Output of Maize in (000, tones)
Ln (OPRICE) = Output of Rice in (000, tones)
Ln (OPSUG) = Output of Sugarcane in (000, tones)
Ln (OPWHEAT) = Output of Wheat in (000, tones)
μ = error term

The present study is based on time series over the period of 1950–2015. The ADF unit root test was applied to assess the stationarity of the variables; non-stationarity could lead to spurious regression results. Such a spurious association between variables might occur in time series data that exhibit non-stationarity.

3.2. Ordinary least square method

The results of this method indicate the predictive ability of the model, as well as the relative statistics of the variables in the short run. To assess the long-run relationship between dependent and independent variables, Johansen's co-integration test is used.

4. Results and discussion

4.1. Results of unit root test

This study used the Augmented Dickey Fuller (ADF) unit root test to assess the stationarity of each variable. The estimated results of the ADF test presented in Table 1 show that none of variables of the attained stationarity at their level form, while all of the variables became stationary after taking the first difference I(1), as indicated by the values of the ADF Statistics test being greater than the critical values at the 5 percent significance level.

4.2. Results of co-integration testing

For co-integration examination based on the method of Johansen, two tests are used: trace statistics and maximum eigenvalues. The presence of co-integration indicates that agricultural gross domestic product, output of wheat, output of rice, output of maize, output of sugarcane and output of cotton have a long-run equilibrium relationship. The estimated results of Johansen's co-integration tests are presented in Tables 2 and 3. The values of trace statistics (110.1580) and the values of the max-eigenstatistic (49.53911), which are greater than their critical values (95.75366), (40.07757), indicate that there exists a long-term relationship amongst the dependent variable and five independent variables, which in turn indicates rejection of the null hypothesis of no co-integration. In both tests, trace statistics and max-eigenstatistics reveal 1 co-integrating equation at the 5 percent level.

4.3. Results of regression

To examine the relationship between the output of major crops and agricultural GDP in Pakistan, the Ordinary Least Square method

Table 1
Results of ADF test.

Variables	ADF Statistic	Critical value	Probability	Level of significance	Order of integration
AGRGDP	−8.345884	−2.907660	0.0000	5 percent	1(1)
OPCOTTON	−12.24537	−2.907660	0.0000	5 percent	1(1)
OPMAIZE	−5.219132	−3.485218	0.0003	5 percent	1(1)
OPRICE	−7.720744	−3.482763	0.0000	5 percent	1(1)
OPSUG	−11.16237	−2.908420	0.0000	5 percent	1(1)
OPWHEAT	−8.621440	−2.908420	0.0000	5 percent	

Source: Author's own calculation using Eviews 9.

Table 2
Johansen co-integration test using trace statistics.

Lags interval: 1 to 1				
Eigenvalue	Trace Statistic	5 Percent critical value	Prob**	Hypothesized no. of CE(s)
0.538858	110.1580	95.75366	0.0033	None[a]
0.380200	60.61891	69.81889	0.1167	At most 1
0.192242	30.00393	47.85613	0.8451	At most 2
0.171079	16.34043	29.79707	0.5468	At most 3
0.065258	4.332065	15.49471	0.8242	At most 4
0.000203	0.013018	3.841466	0.9090	At most 5

** Values are accurate.
Trace test indicates 1 co-integrating equation at the 0.05 level.
[a] Denotes rejection of the hypothesis at the 0.05 level.
Source: Authors' own calculation using Eviews 9.

Table 3
Johansen co-integration test using max-eigen statistic.

Eigenvalue	Max-eigen statistic	5 percent critical value	Prob**	Hypothesized no. of CE(s)
0.538858	49.53911	40.07757	0.0033	None[a]
0.380200	30.61498	33.87687	0.1167	At most 1
0.192242	13.66351	27.58434	0.8451	At most 2
0.171079	12.00836	21.13162	0.5468	At most 3
0.065258	4.319047	14.26460	0.8242	At most 4
0.000203	0.013018	3.841466	0.9090	At most 5

** Values are accurate.
Max-eigenvalue test indicates 1 co-integrating equation at the 0.05 level.
[a] Denotes rejection of the hypothesis at the 0.05 level.
Source: Authors' own calculation using Eviews 9.

was employed. The results of regression analysis are reported in Table 4. From the OLS regression result, the high value of R^2 was 0.931 or 93.1 percent, and the adjusted-R^2 was 0.925 or 92.5 percent. This finding indicates that approximately 93 percent of the total change in agricultural GDP is explained by five explanatory independent variables. The computed value of the F-statistic is 161.9 with a probability value of 0.000000, which shows that the overall fitness of the model is significant.

The results of regression analysis revealed that the coefficient of output of cotton was highly significant at both the 1 percent and 5 percent of significance levels, showing that there was a strong and positive relationship between agricultural GDP and the output of cotton. This finding indicates that a 1 percent increase in the output of cotton increased agricultural GDP by 1.06 percent. The results further showed that the coefficient of output of maize was also highly significant at both 1 percent and 5 percent significance levels, indicating that there is a strong and positive relationship between the output of maize and agricultural GDP. This finding suggests that

Table 4
Regression analysis.

Dependent variable: ln(AGRGDP)				
Method: least squares				
Sample: 1950 2015 Included observations: 66				
Explanatory variables	Coefficient	Std. error	t-Statistic	Prob.
C	1.858653	1.070582	1.736115	0.0877
Ln (OPCOTTON)	1.066188	0.118939	8.964161	0.0000
Ln (OPMAIZE)	0.505505	0.132473	3.815914	0.0003
Ln (OPRICE)	0.210809	0.400113	0.526873	0.6002
Ln (OPSUG)	−0.441224	0.270077	−1.633696	0.1076
Ln (OPWHEAT)	0.095305	0.358341	0.265963	0.7912
R-squared	0.931007	Adjusted R-squared		0.925258
F-statistic	161.9316	Prob(F-statistic)		0.000000
Durbin–Watson stat	1.133231			

a 1 percent increase in the output of maize leads to an increase in agricultural GDP of 0.50 percent. According to Anyanwu et al. (2010), a positive and significant relationship was found between the output of maize and agricultural GDP, whereas the output of rice was statistically insignificant, with a coefficient of 0.210809, indicating that a 1 percent increase in the output of rice would lead to an increase in agricultural GDP of almost 0.21 percent, and the output of wheat was statistically insignificant, with a coefficient of 0.095305, indicating that a 1 percent increase in the output of wheat results in an agricultural GDP increase of 0.09 percent. Currently, the agriculture sector is facing several problems, such as shortages of irrigation, underdeveloped infrastructure facilities, poor agricultural marketing, lack of funding and the rising prices of major agricultural inputs (Chandio et al., 2016). Furthermore, the results showed that there is a negative relationship between the output of sugarcane and agricultural GDP. This result was not expected. The reasons for this negative relationship probably included climate conditions and the ups and down of support prices.

5. Conclusion and recommendations

This study investigated the relationship of agricultural GDP with the outputs of major crops, including wheat, rice, maize, sugarcane and cotton, in Pakistan over the period of 1950–2015. Time series data were collected from Economic Survey of Pakistan (various publications). The ADF unit root test, Johansen's co-integration test and the ordinary least square method were applied to analyse the data. The results of co-integration revealed that there exists a long-term relationship between the outputs of major crops and agricultural GDP of Pakistan. The results of regression analysis also showed that the output of cotton, the output of maize, the output of wheat, and the output of rice have positive relationships with agricultural GDP of Pakistan, while the output of sugarcane has a negative and non-significant relationship with the agricultural GDP of Pakistan. Therefore, this study recommends that the government of Pakistan should launch new funding schemes for the development of the agricultural sector.

References

Abbasi, M.K., Tahir, M.M., Sadiq, A., Iqbal, M., Zafar, M., 2012. Yield and nitrogen use efficiency of rainfed maize response to splitting and nitrogen rates in Kashmir, Pakistan. Agron. J. 104, 448–457.

Ahmad, N., 1998. Plant nutrition management for sustainable agricultural growth in Pakistan. In: Proceedings on Plant Nutrition Management for Sustainable Agricultural Growth. National Fertilizer Development Centre, Planning and Development Division, Government of Pakistan, Islamabad, p. 11.24.

Ahmad, N., 2000. Fertilizer scenario in Pakistan policies and development. In: Proceedings of Conference Agricultural and Fertilizer Use. 2010. NFDC, P and D Division, Government of Pakistan.

Ajayi, O.O.C., 2000. Pesticide Use Practices, Productivity and Farmers' Health: the Case of Cotton-rice Systems in Côte d'Ivoire, West Africa. Pesticide Policy Project Publication Series, Hannover.

Al-Azad, M.A.K., Alam, M.J., 2004. Popularizing of sugarcane based intercropping systems in non mill zone. J. Agron. 3, 159–161.

Anyanwu, S.O., Ibekwe, U.C., Adesope, O.M., 2010. Agriculture share of the gross domestic product and its implications for rural development. Rep. Opin. 2 (8), 26–31.

Arshad, M., Suhail, A., Gogi, M.D., Yaseen, M., Asghar, M., Tayyib, M., Karar, H., Hafeez, F., Ullah, U.N., 2009. Farmers' perceptions of insect pests and pest management practices in Bt cotton in the Punjab, Pakistan. Int. J. Pest Manag. 55, 1–10.

Atlin, G.N., Lafitte, H.R., Tao, D., Laza, M., Amante, M., Courtois, B., 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. Field Crops Res. 97, 43–52.

Atreya, K., 2005. Health costs of pesticide use in a vegetable growing area, central mid-hills, Nepal. Himal. J. Sci. 3, 81–84.

Atreya, K., 2008. Health costs from short-term exposure to pesticides in Nepal. Soc. Sci. Med. 67, 511–519.

Azizullah, A., Khattak, M.N.K., Richter, P., Hader, D., 2011. Water pollution in Pakistan and its impact on public health: a review. Environ. Int. 37, 479–497.

Baloch, M.S., Hassan, G.U.L., Morimoto, T., 2005. Weeding techniques in transplanted and direct wet-seeded rice in Pakistan. Weed Biol. Manag. 5, 190–196.
Banta, S., Mandoza, C.V., 1984. Organic Matter and Rice. International Rice Research Institute (IRRI), Los Baños, Philippines, p. 631.
Barnett, T., Thompson, D.R., 1982. The use of large-area spectral data in wheat yield estimation. Remote Sens. Environ. 12, 509–518.
Berry, S., Dana, P., Spaull, V., Cadet, P., 2009. Effect of intercropping on nematodes in two small-scale sugarcane farming systems in South Africa. Nematropica 39, 11–34.
Bouman, B.A.M., Lampayan, R.M., Tuong, T.P., 2007. In: Water Management in Irrigated Rice: Coping with Water Scarcity. International Rice Research Institute (IRRI), Manila, Philippines, p. 54.
Bouman, B.A.M., Peng, S., Castañeda, A.R., Visperas, R.M., 2005. Yield and water use of irrigated tropical aerobic rice systems. Agric. Water Manag. 74, 87–105.
Briscoe, J., Qamar, U., 2009. Pakistan's Water Economy Running Dry. Oxford University Press, USA.
Bukert, A., Bationo, A., Possa, K., 2000. Mechanism of residue Mulch-induced cereal growth increases in West Africa. Soil Sci. Soc. Am. J. 64, 1–42.
Caballero, R., Goicoechea, E., Hernaiz, P., 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field Crops Res. 41, 135–140.
Carvalho, F.P., 2006. Agriculture, pesticides, food security and food safety. Environ. Sci. Policy 9, 685–692.
CGIAR, 2010. Sustainable Crop Productivity Increase for Global Food Security. A CGIAR Research Program on Rice-Based Production Systems, p. 267.
Chaudhary, R.C., Tran, D.V., Duffy, R., 2001. Speciality Rices of the World: Breed-ing, Production and Marketing. Food and Agriculture Organization (FAO), ROME, Italy.
Chandio, A.A., Yuansheng, J., Magsi, H., 2016. Agricultural sub-sectors performance: an analysis of sector-wise share in agriculture GDP of Pakistan. Int. J. Econ. Finance 8 (2), 156.
Chen, B., Wang, J.J., Zhang, L.M., Li, Z.Y., Xiao, G.L., 2011. Effect of intercropping pepper with sugarcane on populations of *Liriomyza huidobrensis* (Diptera: Agromyzidae) and its parasitoids. Crop Prot. 30, 253–258.
Chen, R., Huang, J., Qiao, F., 2013. Farmers' knowledge on pest management and pesticide use in Bt cotton production in China. China Econ. Rev. 27, 15–24.
Choudhury, A.T.M.A., Kennedy, I.R., 2005. Nitrogen fertilizer losses from rice soils and control of environmental pollution problems. Commun. Soil Sci. Plant Anal. 36, 1625–1639.
Clyma, W.A., Ashraf, M.M., 1975. Irrigation practices and application efficiencies in Pakistan. In: Water Management Research Project: Water Management Technical Report No. 39. Colorado State University, Fort Collins, Colorado, USA.
Damalas, C.A., 2009. Understanding benefits and risks of pesticide use. Sci. Res. Essays 4, 945–949.
Damalas, C.A., Eleftherohorinos, I.G., 2011. Pesticide exposure, safety issues, and risk assessment indicators. Int. J. Environ. Res. Public Health 8, 1402–1419.
Damalas, C.A., Georgiou, E.B., Theodorou, M.G., 2006a. Pesticide use and safety practices among Greek tobacco farmers: a survey. Int. J. Environ. Health Res. 16.
Damalas, C.A., Theodorou, M.G., Georgiou, E.B., 2006b. Attitudes towards pesticide labelling among Greek tobacco farmers. Int. J. Pest Manag. 52, 269–274.
Dasgupta, S., Meisner, C., Huq, M., 2005. Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh. In: W. World Bank Policy Research Working Paper 3776, USA (Ed.).
Deguine, J.P., Ferron, P., Russell, D., 2008. Sustainable pest management for cotton production. A review. Agron. Sustain. Dev. 28, 113–137.
Deressa, T., Hassan, R., Poonyth, D., 2005. Measuring the impact of climate change on South African Agriculture: the case of sugarcane growing regions. Agrekon 44, 524–542.
Dias, M.O.S., Junqueira, T.L., Cavalett, O., Pavaanello, L.G., Cunha, M.P., Jesus, C.D.F., et al., 2013. Biorefineries for the production of first and second generation ethanol and electricity from sugarcane. Appl. Energy 109, 72–78.
Drake, D.J., Nader, G., Forero, L., 2002. Feeding Rice Straw to Cattle. D. o. A. a. N. r. University of California.
Drummond, S.T., Sudduth, K.A., Joshi, A., Birrel, S.J., Kitchen, N.R., 2003. Statistical and neural methods for site-specific yield prediction. Trans. ASAE 46, 5–14.
Eskanddari, H., 2012. Yield and quality of forage produced in intercropping of maize (Zea mays) with cowpea (Vigna sinensis) and mungbean (Vingna radiate) as double cropped. J. Basic Appl. Sci. Res. 2, 93–97.
Fageria, N.K., Baligar, V.C., 2005. Enhancing nitrogen use efficiency in crop plants. Adv. Agron. 88, 97–185.
Fageria, N.K., Baligar, V.C., Clark, R.B., 2006. Physiology of Crop Production. The Haworth Press, New York.
Falkenmark, M., Fox, P., Persson, G., Rockstorm, J., 2001. Water Harvesting for Upgrading of Rainfed Agriculture: Problems Analysis and Research Needs. Stockholm International Water Institute, Stockholm.
Fantke, P., Friedrick, R., Jolliet, O., 2012. Health impact and damage cost assessment of pesticides in Europe. Environ. Int. 49, 9–17.
FAO, 2000. Crops and Drops: Making the Best Use of Water for Agriculture. FAO Advance Edition, Rome, Italy.
FAO, 2009. World Summit on Food Security. FAO, Rome.
FAO, 2012. Food and Agriculture Organization of United Nations.
FAOSTAT, 2015. Food and Agriculture Organization of the United Nations: Statistics Division. FAOSTAT.
Farooq, M., Siddique, K.H.M., Rehman, H., Aziz, T., Lee, D.J., Wahid, A., 2011. Rice direct seeding: experiences, challenges and opportunities. Soil Tillage Res. 111, 87–98.
Fitt, G.P., 2000. An Australian approach to IPM in cotton: integrating new technologies to minimize insecticide dependence. Crop Prot. 19, 793–800.
Fraiture, C.D., Molden, D., Wichetns, D., 2010. Investing in water for food, ecosystem and livelihoods: an overview of the comprehensive assessment of water management in agriculture. Agric. Water Manag. 97, 495–501.
Gamuyao, R., Chin, J.H., Pariasca-Tanaka, J., Pesaresi, P., Catausan, S., Dalid, C., Slamet-Loedin, I., Tecson-Mendoza, E.M., Wissuwa, M., Heuer, S., 2012. The protein kinase Pstol1 from traditional rice confers tolerance of phosphorus deficiency. Nature 488, 535–539.
Ghosh, P.K., 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Res. 88, 227–237.
Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. CAB International, Wallingford, UK, p. 423.
Girei, A.A., Giroh, D., 2012. Analysis of the factors affecting sugarcane (*Saccharum officinarum*) production under the out grower's scheme in Numan Local Government Area Adamawa State, Nigeria. Adv. Agric. Sci. Eng. Res. 2, 195–200.
Glass, A.D.M., 2003. Nitrogen use efficiency of crop plants: physiological constraints upon nitrogen absorption. Crit. Rev. Plant Sci. 22, 453–470.
GOP, 2012. Pakistan economic survey 2010–11. In: Economic Advisory Wing Finance Division. Government of Pakistan, Islamabad, Pakistan.
Harris, D., Natarajan, M., Willey, R., 1987. Physiological basis for yield advantage in a sorghum/groundnut intercrop exposed to drought. 1. Dry-matter production, yield, and light interception. Field Crops Res. 17, 259–272.
Hashemi, S.M., Damalas, C.A., 2011. Farmer's perceptions of pesticide efficacy: reflections on the importance of pest management practices adoption. J. Sustain. Agric. 35, 69–85.
Hashemi, S.M., Rostami, R., Hashemi, M.K., Damalas, C.A., 2012. Pesticide use and risk perceptions among farmers in southwest Iran. Hum. Ecol. Risk. Assess. 18, 456–470.
Hayes, M.J., Decker, W.L., 1996. Using NOAA AVHRR data to estimate maize production in the United States Corn Belt. Int. J. Remote Sens. 17, 3189–3200.
Hazell, P., 2010. The Green Revolution. International Food Policy Research Institute, Washington, DC.
Heisey, P.W., 1990. Accelerating the Transfer of Wheat Breeding Gains to Farmers: a Study of the Dynamics of Varietal Replacement in Pakistan, vol. 1. CIMMYT Research, Mexico, D.F.
Heisey, P.W., Edmeades, G.O., 1999. Maize production in drought-stressed environments: technical options and research resource allocation. In: World Maize Facts and Trends 1997/1998. CIMMYT.
Herridge, D.F., Doyle, A.D., 1988. The narrow leafed lupin (Lupinus angustifolius L.) as a nitrogen fixing rotation crop for cereal production. 2: estimates of fixation by field grown crops. Aust. J. Agric. Res. 39, 1017–1028.
Herridge, D.F., Marcellos, H., Felton, W., Schwenke, G., Aslam, M., Ali, S., Shah, Z., Shah, S.H., Maskey, S., Bhuttari, S., Peoples, M.B., Turner, G., 1995. Management of legume N_2 fixation in cereal system. A research program for rainfed areas of Pakistan, Nepal, and Australia. In: Proceedings of IAEA/FAO International Symposium on Nuc. and Related Tech. in Soil/Plant Studies on Sustainable Agriculture and Environmental Preservation, pp. 237–250. Vienna, Austria.
Hijmans, R.J., Condori, B., Carillo, R., Kropff, M.J., 2003. A quantitative and constraint specific method to assess the potential impact of new agricultural technology: the case of frost resistant potato for the Altiplano (Peru and Bolivia). Agric. Syst. 76, 895–911.
Huang, C.L., 1993. Simultaneous-equation model for estimating consumer risk perception, attitudes and willingness-to-pay for residue-free produce. J. Consum. Aff. 27, 377–396.
Huang, Y., Lan, Y., Thomson, S.J., Fang, A., Hoffmann, W.C., Lacey, R.E., 2010. Development of soft computing and applications in agricultural and biological engineering. Comput. Electron. Agric. 71, 107–127.
Hussain, T., 2002. Groundwater management: a case study of Rechna Doab – Pakistan. J. Drain. Water Manag. 6, 69–76.
Imam, S., Hossain, A.D., Sikka, L., Midmore, D., 1990. Agronomic management of potato/sugarcane intercropping and its economic implications. Field Crops Res. 25, 111–122.
IPCC, 2006. NO_2 emission from managed soil and CO_2 emission from lime and urea application. In: Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use, vol. 4. Geneva, Switzerland.
Iqbal, M., Kham, M.A., Ahmad, M., 2002. Adoption of recommended varieties: a farm-level analysis of wheat growers in irrigated Punjab. Pak. Dev. Rev. 29–48.
Iqbal, Z., Zia, K., Ahmad, A., 1997. Pesticide abuse in Pakistan and associated human health and environmental risks. Pak. J. Agric. Sci. 34, 94–97.
Iqtidar, H., Ayyaz, K.M., Ahmad, K.E., 2006. Bread wheat varieties as influenced by different nitrogen levels. J. Zhejiang Univ. Sci. 7, 70–78.
Irmak, A., Jones, J.W., Batchelor, W.D., Irmak, S., Boote, K.J., Paz, J.O., 2006. Artificial neural network model as a data analysis tool in precision farming. Am. Soc. Agric. Biol. Eng. 49, 2027–2037.
IRRI, 1978. Rice and Soils. International Rice Research Institute, Los Baños, Philippines, p. 825.
IRRI, 1985. Wetland Soils: Characterization, Classification, and Utilization. International Rice Research Institute, Los Baños, Philippines, p. 559.
IRRI, 2010. Developing and Disseminating Water-saving Rice Technologies in South Asia. International Rice Research Institute (IRRI), Manila, Philippines, p. 58.
Jabbar, A., Mallick, S., 1994. Pesticide and Environmental Situation in Pakistan. Sustainable Development Policy Institute (SDPI), Islamabad, Pakistan. Working Paper Series No.19.

Jensen, E.S., 1996. Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant Soil 182, 25–38.
Kahlown, M.A., Kemper, W.D., 2004. Seepage losses as affected by condition and composition of channel banks. J. Agric. Water Manag. 65, 145–153.
Kahlown, M.A., Raoof, A., Hanif, M., 2001. Plant population effect on paddy yield. J. Drain. Water Manag. 5, 1–5.
Kahlown, M.A., Raoof, A., Zubair, M., Kemper, W.D., 2007. Water use efficiency and economic feasibility of growing rice and wheat with sprinkler irrigation in the Indus Basin of Pakistan. Agric. Water Manag. 87, 292–298.
Kahlown, M.A., Shafique, M.S., Iqbal, M., 1998. Improved irrigation methods for efficient use of irrigation water under different water-table depths. In: Mona Reclamation Experimental Project. WAPDA, Bhalwal.
Kawaguchi, K., Kyuma, K., 1977. Paddy Soils in Tropical Asia: Their Material Nature and Fertility. Monographs of the Center for Southeast Asian StudiesKyoto University, p. 258.
Khan, M., Damalas, C.A., 2015. Factors preventing the adoption of alternatives to chemical pest control among Pakistani cotton farmers. Int. J. Pest Manag. 61, 9–16.
Khan, M., Mahmood, H.Z., Damalas, C.A., 2015. Pesticide use and risk perceptions among farmers in the cotton belt of Punjab, Pakistan. Crop Prot. 67, 184–190.
Khan, R.U., Durrani, F.R., Chand, N., Anwar, H., 2010. Influence of feed supplementation with Cannabis sativa on quality of broilers carcass. Pak. Vet. J. 30, 34–38.
Khan, S., Tariq, R., Yuanlai, C., Blackwell, J., 2006. Can irrigation be sustainable? Agric. Water Manag. 80, 87–99.
Kijne, J.W., Kuper, M., 1995. Salinity and sodicity in Pakistan's Punjab: a threat to sustainability of irrigated agriculture? J. Int. Water Resour. Dev. 11, 73–86.
Kirk, G.J.D., 2004. The Biogeochemistry of Submerged Soils. John Wiley & Sons, Chichester, UK.
Kishi, M., Hirschhorn, N., Djajadisastra, M., Satterlee, L.N., Strowman, S., Dilts, R., 1995. Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. Scand. J. Work Environ. Health 21, 124–133.
Kögel-Knabner, I., Amelung, W., Cao, Z., Fiedler, S., Frenzel, P., Jahn, R., Kalbitz, K., Kölbl, A., Schloter, M., 2010. Biogeochemistry of paddy soils. Geoderma 157, 1–14.
Ladha, J.K., George, T., Bohlool, B.B., 1992. Biological Nitrogen Fixation for Sustainable Agriculture. Kluwer Academic Publishers, Dordrecht, Neatherlands.
Ladha, J.K., Pathack, H., Krupnik, T.J., Six, J., Kessel, C.V., 2005. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. Adv. Agron. 87, 85–156.
Lal, R., 1980. Soil erosion as a constraint to crop production. In: Priorities for Alleviating Soil Related Constraints to Food Production in Tropics. Int. Rice Res. Inst., Los Banos, pp. 405–423.
Li, C.Y., He, X.H., Zhu, S.S., Zhu, H.P., Wang, Y.Y., Li, Y., Yang, J., Fan, J.X., Yang, J.C., Wang, G.B., Long, Y.F., Xu, J.Y., Tang, Y.S., Zhao, G.H., Yang, J.R., Liu, L., Sun, Y., Xie, Y., Wang, H.N., Zhu, Y.Y., 2009. Crop diversity for yield increase. PLoS One 4, 1–6.
Li, Q.Z., Sun, J.H., Wei, X.J., Christie, P., Zhang, F.S., Li, L., 2011. Over yielding and interspecific interactions mediated by nitrogen fertilization in strip intercropping of maize with faba bean, wheat and barley. Plant Soil 339, 147–161.
Liu, E.M., Huang, J., 2013. Risk preferences and pesticide use by cotton farmers in China. J. Dev. Econ. 103, 202–215.
Maclean, J.L., Dawe, D., Hardy, B., Hettel, G.P., 2002. Rice Almanac. International Rice Research Institute (IRRI), Manila, Philippines.
Maroni, M., Fanetti, A.C., Metruccio, F., 2006. Risk assessment and management of occupational exposure to pesticides in agriculture. Med. Lav. 97, 430–437.
Maurya, P.R., 1981. Effects of different mulch materials on soil properties and on root growth and yield of maize (*Zea mays*) and cow pea (*Vigna uniguiculata*). Field Crops Res. 4, 33–45.
McDonald, G.K., 1989. The contribution of nitrogen fertilizer to the nitrogen nutrition of rainfed wheat (*Triticum aestivum*) crops in Australia: a review. Aust. J. Exp. Agric. 29, 455–481.
McDonald, G.K., 1992. Effects of nitrogenous fertilizer on the growth, grain yield and grain protein concentration of wheat. Aust. J. Agric. Res. 43, 949–967.
Midega, C.A.O., Nyang'au, I.M., Pittchar, J., Birkett, M.A., Pickett, J.A., Borges, M., Khan, Z.R., 2012. Farmers' perceptions of cotton pests and their management in western Kenya. Crop Prot. 42, 193–201.
Moormann, F.R., Breemen, N.V., 1978. Rice: Soil, Water, Land. International Rice Research Institute (IRRI), Los Baños, Philippines, p. 185.
Munyinda, K., Karamanos, R.E., O'Halloran, I.P., 1988. Yields of wheat in rotation with maize and soybeans in Zambia. Can. J. Soil Sci. 68, 747–753.
Nazir, M.S., Jabbar, A., Ahmad, I., Nawaz, S., Bhatti, H.I., 2002. Production potential and economics of intercropping in autumn-planted sugarcane. Int. J. Agric. Biol. 4, 140–142.
Nguyen, T.D., Han, E.M., Seo, M.S., Kim, S.R., Yun, M.Y., Lee, D.M., Lee, G.H., 2008. A multi-residue method for the determination of 203 pesticides in rice paddies using gas chromatography/mass spectrometry. Anal. Chim. Acta 619, 67–74.
Ochou, G.O., Matthews, G.A., Mumford, J.D., 1998. Farmer's knowledge and perception of cotton insect pest problems in C^ote d'Ivoire. Int. J. Pest Manag. 44, 5–9.
Oerke, E.C., 2006. Crop losses to pests. J. Agric. Sci. 144, 31–43.
Oweis, T., 1997. Supplemental Irrigation: a Highly Efficient Water-use Practice. ICARDA, Aleppo, Syria, p. 16.
Oweis, T., Hachum, A., 2003. Improving water productivity in the dry areas of West Asia and North Africa. In: Kijne, W.J., Barker, R., Molden, D. (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford, pp. 179–197.
Oweis, T., Hachum, A., 2004. Water harvesting and supplemental irrigation for improved water productivity of dry farming system in West Asia and North Africa. New direction for a diverse planet. In: Proceeding of the 4th International Crop Science Congress, Brisbane, Australia.
Pakistan, E. S. o, 2008-09. Economic Survey of Pakistan. Government of Pakistan, Finance Division Economic Adviser's Wing, Islamabad, p. 21.
Pakistan, E. S. o, 2012-13. Economic Survey of Pakistan. Government of Pakistan. Finance Division Economic Adviser's Wing, Islamabad.
Pandey, S., Mortimer, M., Wade, L., Tuong, T.P., Lopez, K., Hardy, B., 2002. Direct seed-ing: research issues and opportunities. In: International Workshop on Direct Seeding in Asian Rice Systems: Strategic Research Issues and Opportunitie. International Rice Research Institute, Bangkok, Thailand, p. 383. LosBaños (Philippines).
Pandey, S., Velasco, L., 2005. Trends in crop establishment methods in Asia and research issues. In: Rice is Life: Scientific Perspectives for the 21st Century, pp. 178–181.
Parthasarathy, B., Munot, A.A., Kothawale, D.R., 1988. Regression model for estimation of Indian food grain production from summer monsoon rainfall. Agric. For. Meteorol 42, 167–182.
PCCC, 2008. Annual progress report of Central Cotton Research Institute 2007–08. In: Pakistan Central Cotton Committee, Multan, Pakistan. Pakistan Central Cotton Committee, Multan, Pakistan.
Peoples, M.B., Craswell, E.T., 1992. Biological nitrogen fixation: investments, expectations and actual contributions to agriculture. Plant Soil 141, 13–39.
Pimental, D., 2005. Environmental and economic costs of the application of pesticides primarily in the United States. Environ. Dev. Sustain. 7, 229–252.
Ponnamperuma, F.N., 1972. The chemistry of submerged soils. Adv. Agron. 24, 29–96.
Prasad, R., Donald, L.S., 2011. Aerobic rice systems. In: Advances in Agronomy. Academic Press, pp. 207–247.
Qiang, Z., Yuanhong, L., Manjin, C., 2006. Effect of low rate irrigation with rainwater harvesting system on the dry farming. In: Proceedings of the 2nd International RWHM Workshop, Beijing.
Ramotra, K.C., Giakwad, V.P., 2012. Surface rain harvesting potentiality and impact of Dhaval micro-watershed in Satara district, Maharashtra, India. J. Environ. Earth Sci. 2, 28–38.
Ranuzzi, A., Srivastava, R., 2012. Impact of climate change on agriculture and food security. ICRIER Policy Ser. 16.
Renkow, M., 2000. Poverty, productivity and production environment: a review of the evidence. Food Policy 25, 463–478.
Robinson, N., Brackin, R., Vinall, K., Soper, F., Holst, J., Gamage, H., Paungfoo-Lonhienne, C., Rennenberg, H., Lakshmanan, P., Schmidt, S., 2011. Nitrate paradigm does not hold up for sugarcane. PLoS One 6, 19036–19045.
Rogelio, N.C., Samuel, M.C., Wilfredo, B.S., Arnulfo, B.G., Gina, P.N., Karen, A.S., Katherine, M.M., Sharon, V., de, V., 2006. Enhancing multi-functionality of agriculture through rainwater harvesting system. Paddy Water Environ. 4, 235–243.
Rosegrant, M.W., Cai, X., 2000. Modeling water availability and food security—a global perspective: the IMPACT-water model. In: Working Draft. International Food Policy Research Institute, Washington, DC.
Ruan, W.R., Johnson, G.V., 1999. Improving nitrogen use efficiency for cereal production. Agron. J. 91, 357–363.
Ruan, W.R., Sloie, J.B., Johnson, G.V., Stone, M.L., Mullen, R.W., Freeman, K.W., Thomason, W.E., Lukina, V., 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. Agron. J. 94, 815–820.
Seregeldin, I., 1999. Looking ahead: water, life and the environment in the 21st century. J. Int. Water Resour. Dev. 15, 17–27.
Shafiq, M., Rehman, T., 2000. The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: an application of data envelopment analysis. Agric. Econ. 22, 321–330.
Shah, Z., Shah, S.H., Herriedge, D.F., Peoples, M.B., Aslam, M., Ali, S., Tariq, M.T., 1995. Pakistan's agriculture-cereal and legume production. J. Agric. Univ. Wales Aberyswyth U. K. 75, 89–98.
Shah, Z., Shah, S.H., Peoples, M.B., Schwenke, G.D., Herriedge, D.F., 2003. Crop residue and fertilizer N effects on nitrogen fixation and yields of legume–cereal rotations and soil organic fertility. Field Crops Res. 83, 1–11.
Sharif, A., 2011. Technical adaptations for mechanized SRI production to achieve water saving and increased profitability in Punjab, Pakistan. Paddy Water Environ. 9, 111–119.
Sharma, S.K., 1984. Principles and Practices of Irrigation Engineering. IBH Publication Co, New York: Oxford.
Shaumarov, M., Birner, R., 2013. Dryland pastoral systems in transition: what are the options for institutional change in Uzbekistan?. In: 53rd Annual Conference of the German Society of Economic and Social Sciences in Agriculture (GEWISOLA), pp. 1–16. Berlin.
Shideed, K.H., 2011. Informing Policy Development for Sustainable and Productive Food Production Systems in Dry Areas. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.
Short, R., Lantzke, N., 2006. Increasing Runoff from Roaded Catchments by Chemical Application. Department of Agriculture and Food, Western Australia, pp. 20–24.
Singh, A.N., Singh, U.S., 2010. Targeted Dissemination of Stress-tolerant Rice Varieties: Propagating Swarna-sub1, Sahbhagi Dhan, and CSR36 in Uttar Pradesh, India, vol. 3,4. STRASA NEWS.

Sinzogan, A.A.C., Huis, A.V., Kossou, D.K., Jiggins, J., Vodouhe, S., 2004. Farmer's knowledge and perception of cotton pests and pest control practices in Benin: results of a diagnostic study. NJAS Wageningen J. Life Sci. 52, 285–303.
Sjoberg, L., 2000. Factors in risk perception. Risk Anal. 20, 1–11.
Smale, M., Reynolds, M.P., Warburton, M., Skovmand, B., Trethrowan, R., Singh, R.P., Ortiz-Monasterio, I., Crossa, J., 2002. Dimensions of diversity in modern spring bread wheat in developing countries from 1965. Crop Sci. 42, 1766–1779.
Soares, W.L., Porto, M.F.D., 2009. Estimating the social cost of pesticide use: an assessment from acute poisoning in Brazil. Ecol. Econ. 68, 2721–2728.
Spanu, A.G., Andria, P.R., Lavini, A., Chiranda, F.Q., 1996. Yield response of rice to increasing sprinkler irrigation. J. Int. Comm. Irri. Drain. 45, 56–66.
Strong, W.M., Harbison, J., Nielson, R.G.H., Hall, B.D., Best, E.K., 1986. Nitrogen availability in a Darling Downs soil following cereal, oilseed and grain legume crops. 2. Effects of residual soil nitrogen and fertiliser nitrogen on subsequent wheat crops. Aust. J. Exp. Agric. 26, 347–351.
Suleimenov, M., Saparov, A., Akshalov, K., Kaskarbayev, Z., 2011. VI-6 Land degradation issues in Kazakhstan and measures to address them: research and adoption. Jap. Soc. Soil Sci. Plant Nutr. Abstr. 57, 225.
Tariq, M.I., Afzal, S., Hussain, I., Sultana, N., 2007. Pesticides exposure in Pakistan: a review. Environ. Int. 33, 1107–1122.
Tavakkoli, A.R., Oweis, T.Y., 2004. The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. Agric. Water Manag. 65, 225–236.
Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418, 667–671.
Valipour, M., 2013. Increasing irrigation efficiency by management strategies: cutback and surge irrigation. ARPN J. Agric. Biol. Sci. 8, 35–43.
Vandermeer, J.H., 1990. Intercropping. In: Carroll, C.R., Vandermeer, J.H., Rosset, P.M. (Eds.), Agroecology. McGraw-Hill Inc, New York, pp. 481–516.
Verulkar, S.B., Mandal, N.P., Dwivedi, J.L., Singh, B.N., Sinha, P.K., Mahato, R.N., Swain, P., Dongre, P., Payasi, D., Singh, O.N., Bose, L.K., Robin, S., Chandrababu, R., Senthil, S., Jain, A., Shashidhar, H.E., Hittalmani, S., Cruz, C.V., Paris, T., Robert, H., Raman, A., Haefele, S.M., Serraj, R., Atlin, G., Kumar, A., 2010. Breeding resilient and productive genotypes adapted to drought prone rainfed ecosystem of India. Field Crops Res. 117, 197–208.
Wassmann, R., Lantin, R.S., Neue, H.U., 2000. Methane emissions from major rice ecosystems. Special Issue 'Nutrient Cycl. Agroecosystems' 58.
Werf, H.M.G.V.D., 1996. Assessing the impact of pesticides on the environment. Agric. Ecosyst. Environ. 60, 81–96.
Xie, K.Z., Wang, Y.J., Li, F.M., 2005. Effect of plastic mulching on soil water use and spring wheat yield in arid region of northwest China. Agric. Water Manag. 75, 71–83.
Xu, B.C., Li, F.M., Shan, L., 2008. Switchgrass and milkvetch intercropping under 2:1 row replacement in semiarid region, northwest China: aboveground biomass and water use efficiency. Eur. J. Agron. 28, 485–492.
Xu, K., Xu, X., Fukao, T., Canlas, P., Maghirang-Rodriguez, M., Heuer, S., Ismail, A.M., Bailey-Serres, J., Ronald, P.C., Mackill, D.J., 2006. Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice. Nature 442, 705–708.
Yang, P., Iles, M., Yan, S., Jolliffe, F., 2005. Farmers' knowledge, perceptions and practices in transgenic Bt cotton in small producer systems in Northern China. Crop Prot. 24, 229–239.
Zakaria, S., Al-Ansari, N., Knutsson, S., 2013. Wheat yield scenarios for rainwater harvesting at Northern Sinjar Mountain, Iraq. Nat. Sci. 5, 1057–1068.
Zakaria, S., AL-Ansari, N.A., Knutsson, S., EZZ-Al-deen, M., 2012. Rain water harvesting at Eastern Sinjar Mountain. Iraq Geosci. Res. 3, 100–108.
Zapata, F., Cleenput, O.V., 1986. Recovery of N15 labeled fertilizer by sugar beet spring wheat and winter sugar beet cropping sequences. Fertil. Res. 8, 269–278.