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EFFECT OF CLIMATE CHANGE ON APPLE (*MALUS DOMESTICA* var. *AMBRI*) PRODUCTION: A CASE STUDY IN KOTLI SATIAN, RAWALPINDI, PAKISTAN

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Abstract

Study was undertaken to investigate the long term and short term effect of climate change on apple production in Kotli Sattian area of Rawalpindi District, using *Malus domestica* var. Ambri L. as an indicator. Climate data for previous 30 years (i.e. 1979-2009) was correlated with net apple production per year. The study also explored other supporting ecological factors like metal content analysis and current soil status (pH, moisture content, organic matter, soil texture) of the orchard's soil. This investigation revealed that all physico-chemical parameters were supporting production but it declined mainly due to drastic climate change aspects including unusual seasonal variations, elongated summer periods and unusual rainfall periods. In context of questionnaires results, an overwhelming number of farmers (91%) were of the opinion that climate change was the main factor behind decline apple production. The case study served as an effort to bring awareness in the local farmers about the devastating effects of climate changes to help them and improve apple production in Pakistan through enhanced agricultural practices.

Introduction

Apple is a fruit of temperate climate and native in many parts of Europe and Asia (Sandor, 2008). Worldwide, apple is the fourth most extensively produced deciduous fruit, in 94 countries its production was 69.60 million metric tons fresh-weight yield from 4.85 million hectares of land (Anon., 2010).The global climate is changing and will continue to change in future according to the Fourth Assessment Report of the UN International Panel on Climate Change (Anon., 2007). Since 1850 eleven years (1995–2006) have been found as the warmest years (Anon., 2007). Due to the change in weather pattern, crop production is affected in addition to the threats to food security as an impact of climate change (Stern, 2007; Miraglia *et al*., 2009). There is variation from place to place in the production of crop yield as a result of climate change (Supit *et al*., 2010; Olesen *et al*., 2011). Impact of climate change on agriculture is getting increasing importance these days. It affects the flowering, blooming time, color, size and shapes of apple (Slingo, 2009). Soils tend to show a strong geographical correlation with climate, especially at the global scale. As time passes, climate tends to be a prime influence on soil properties while the influence of parent material was less (Ritter, 2006). Energy and precipitation strongly influence physical and chemical reactions on parent material. Climate also determines a vegetation cover which in turn influences soil development. Precipitation also affects horizon development factors like the translocation of dissolved ions through the soil (Slingo, 2009) & Weil, 2007).

In northern areas of Pakistan especially Kashmir, Murree and Kotli Satian, apple farming serves as a primary source of income. One of the finest varieties of Ambri apple (*Malus domestica* var. Ambri L.) is cultivated in Kotli Satian. It is a climate sensitive crop. Due to obvious change in climatic pattern, apple is taken as an indicator crop in the present study to investigate the effects of climate change on apple production and farmers economy. Study also explores the other supporting ecological factors such as current soil status in the area that is supportive element for increased production levels. This investigation is an attempt to answer whether production of apple is affected by climatic changes and current soil status supportive Ambri apple production in Kotli Sattian study area.

Study area: This Study was conducted in Kotli Satian area, lying between North Latitude 33º 65' 714" and East latitudes of 73º 03' 008" in Rawalpindi District at an elevation of 1523 m above sea level. Pakistan (Fig. 1). Its meteorological data for temperature, rainfall pattern for last 30 consecutive years was taken from Pakistan Metrological office, Islamabad to correlate with net apple production per year.

Methodology: Four mature apple orchards were selected for apple production count. Total area covered by Orchard 1, 2, 3 and 4 covers was 200m by 50m, 300m by 100m, 300m by 130m, 200m by 50m respectively. Geographical coordinates of sampling sites were recorded using GPS (Garmin, Geko 301).

Composite soil sampling was performed from each orchard. Soil samples were air dried at room temperature and sieved through 2mm sieve to remove the coarse particles and debris. Soil samples were analyzed for pH, EC and TDS using the combined digital pH meter (Milwaukee SM802) in a soil solution of 1:10 ratio. Moisture content (%) of soils was determined (Nikolskii, 1963). Organic matter was determined by Tyurin's method (Nikolskii, 1963). Soil textural classes were determined by using the textural triangle (Robert & Frederick, 1995). The soil acid digests were prepared for the determination of total content of soil nutrients and heavy metals (USEPA Method 3051a). Nutrient concentrations (Ca, Mg, Na and K) and heavy metal concentrations (Cd, Cr, Pb, Ni, Cu, Zn) in the extracts was measured using atomic absorption spectrophotometer (Varian FSS-240).

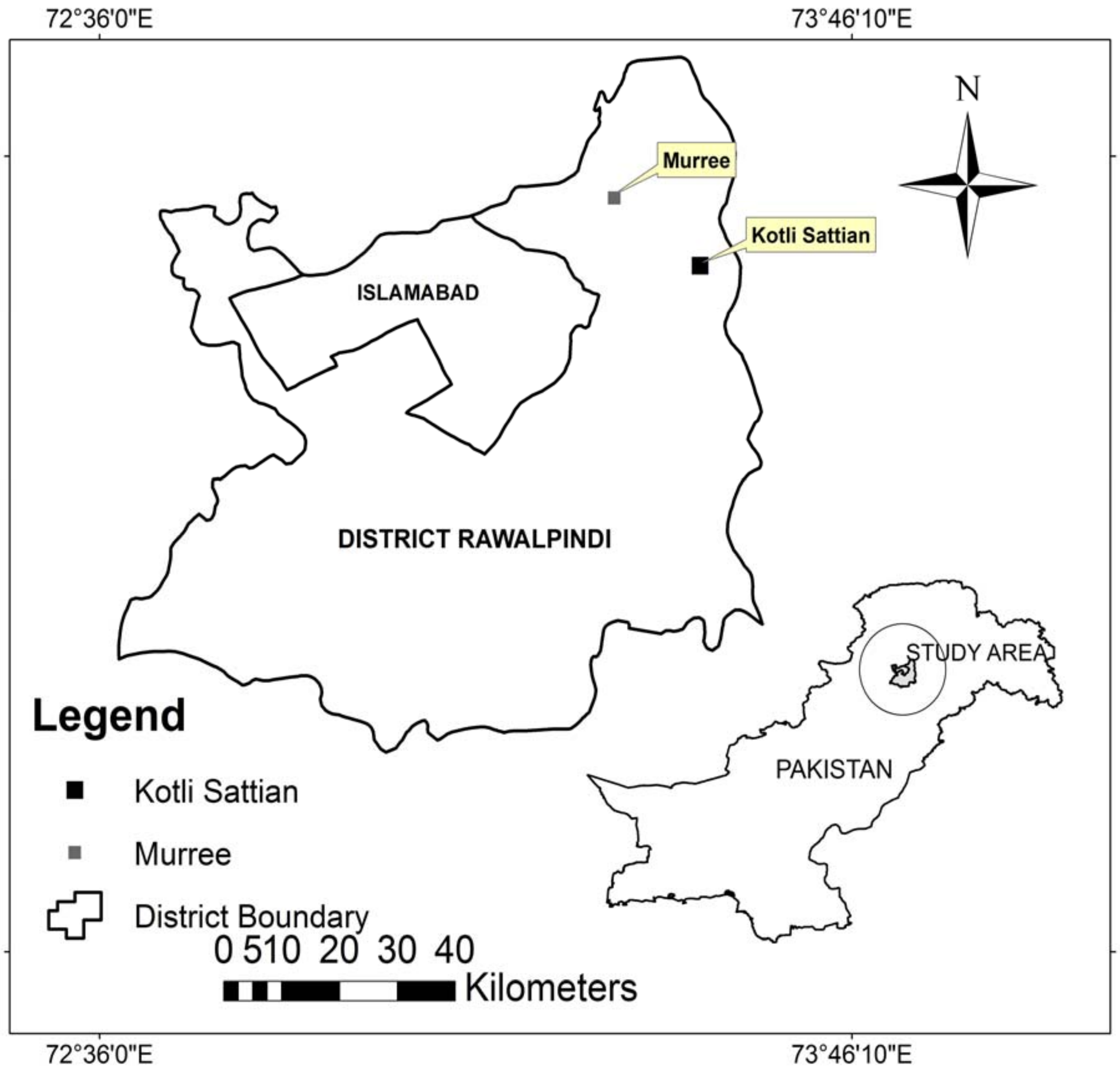

Fig. 1. Site map of study area.

Questionnaires were prepared to target the local farmers directly. It served as the most vital source of primary information as they experienced the direct effects of changing weather patterns and climate change on apple production and livelihood. Data was analyzed using Statistica Version 8. Descriptive statistics such as mean, standard error, minimum, maximum, standard deviation, and variance were carried out. Box and whiskers were plotted to show heavy metal content in the soils of apple orchards to show the mean values along with the standard errors.

Results and Discussion

In context of global warming, the general trend towards earlier flowering dates of many temperate tree species linked in an increased risk of damage from exposure to frost and other seasonal variations (Emanuele *et al*., 2008). Apple production results for the last thirty years showed variations in the production level (Table. 1). Results showed a strong correlation with the changing seasonal variations i.e. rainfall and temperature (Fig. 2 and 3). Retention ability is affected in case of high and even low temperatures. Lack of precipitation inhibits chemical weathering leading to coarse textured soil in arid regions (Ritter, 2006). Apple production decreased significantly due to temperature and rainfall fluctuation. The changing temperature and radiation patterns leads to decrease/increase or to the stagnation yield potential of few crops (Supit *et al*., 2010). Remarkable decline in apple production was observed in years 1999, 2002, 2001 and 2004 and drastic climatic changes were recorded like extreme temperature rise and high precipitation. These abrupt changes in weather pattern resulted in decreased production and ultimately it declined to zero in 2009 because of unusual snow falls in the month of April which resulted in complete destruction of flowers. Extreme weather conditions like strong wind and abrupt changes in the rainfall pattern causes removal of the top soil in short duration thus destroying soil capability to support vegetation (Neilson & Neilson, 2003).

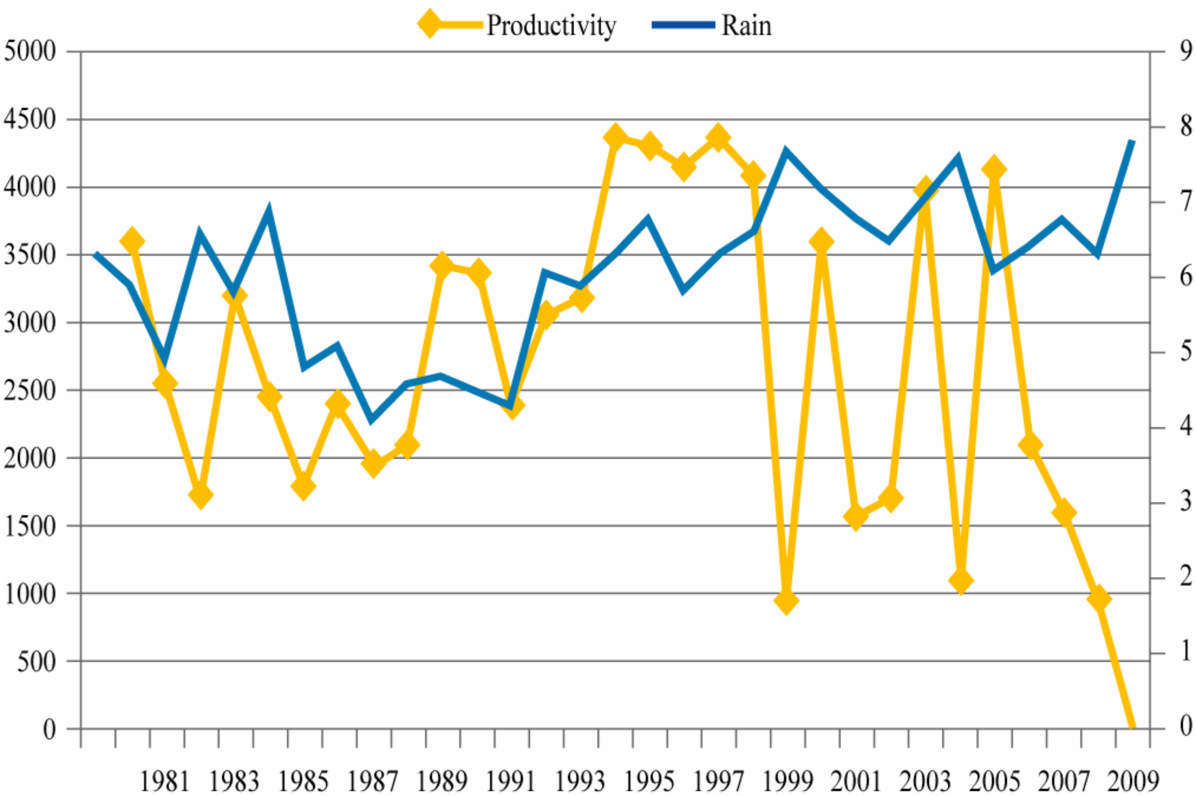

Fig. 2. Comparison between rainfall (mm) and apple production (Kg/year).

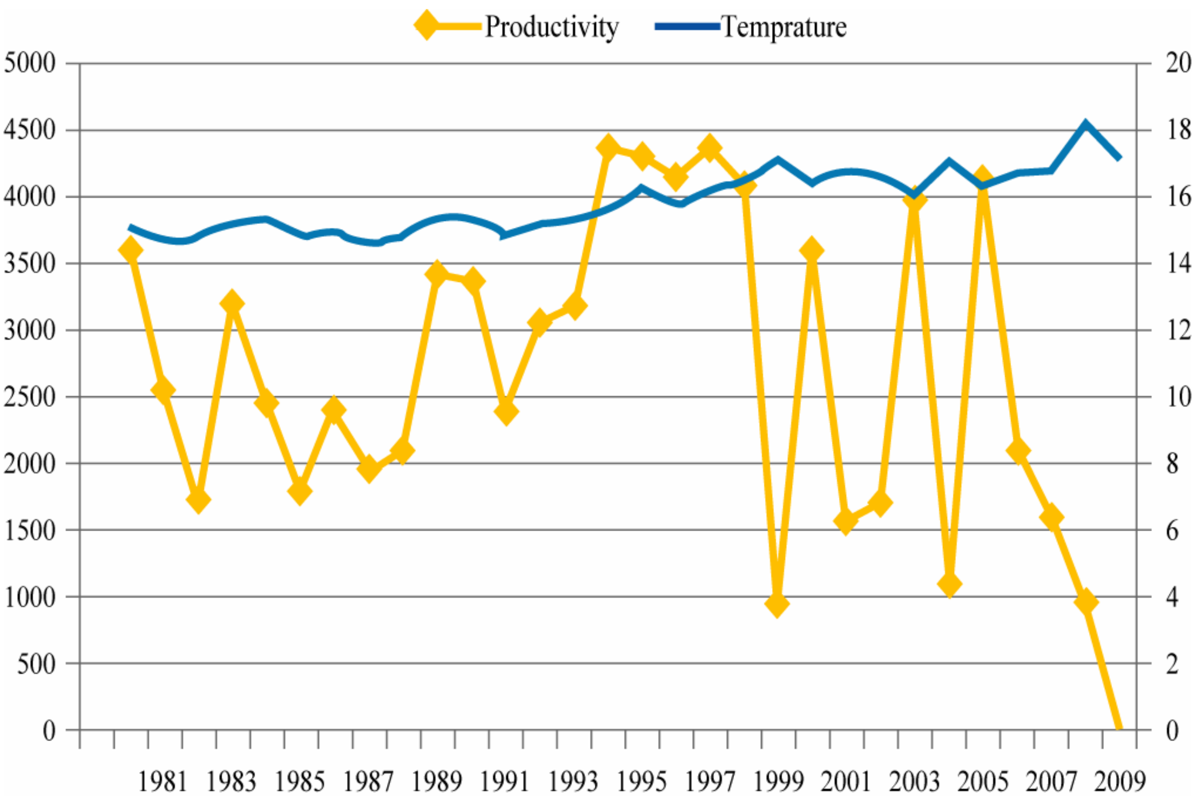

Fig. 3. Comparison between temperature (°C) and apple production (Kg/year).

Table 1. Apple production of 4 orchards under observation.

Year	Orchard1	Orchard 2	Orchard 3	Orchard 4	Production (Kg/year)
1980	550	1160	1300	590	3600
1981	350	800	940	410	2560
1982	330	480	610	330	1750
1983	490	810	1370	530	3200
1984	420	610	950	470	2450
1985	310	440	710	340	1800
1986	490	590	810	510	2400
1987	360	480	71	410	1960
1988	390	520	760	430	2100
1989	520	990	1410	480	3400
1990	570	870	1380	530	3350
1991	410	470	820	680	2380
1992	410	850	1200	590	3050
1993	490	760	1320	600	3170
1994	830	1110	1630	780	4350
1995	840	980	1590	890	4300
1996	910	770	1530	940	4150
1997	870	1030	1520	940	4360
1998	690	970	1580	810	4050
1999	190	230	370	160	950
2000	580	860	1510	630	3580
2001	190	370	780	230	1570
2002	310	430	630	330	1700
2003	730	990	1480	770	3970
2004	110	270	370	350	1100
2005	910	1020	1320	870	4120
2006	410	530	720	440	2100
2007	270	390	650	290	1600
2008	170	280	320	180	950
2009	0	0	0	0	0

Maintenance of healthy and productive apple orchards require proper moisture content. Orchard soils showed a mean value of 74% moisture content fairly good to support high productivity. This value varied between 35--142. Excessive soil moisture also provides an ideal environment for crown and collar rots, while insufficient moisture results in drought, stress and reduces fruit quality (Black *et al*., 2008). Surface soils were found to be slightly basic with an average pH of 8.55 (Fig. 4). This proves to be supportive for production except for year 2009 when drastic change in the production level of apple was correlated directly to the sudden and severe snowfall at an unexpected time period. Bacterial activity hinders in case of unexpected cold temperatures and decomposing activities reduced in orchards therefore reducing organic matter content not sufficient to support apple production. Box and whisker plots demonstrated highest mean values for moisture content while in comparison it was low for soil particles (sand, silt and clay) and organic matter (Fig. 4). These changing weather patterns contributed much to the decreased production level of apples in the area.

In addition to deposition of pollutants in the soil, it also altered chemical characteristics such as pH value affecting availability of nutrients and increasing the leaching of minerals from the soil (Oren, 1996). It may also result in deficiencies of the nutrients (, mainly Mg, Ca and K) in plants along with severe nutritional imbalances. Chemical elements (Ca, Mg, Na, K and Zn) are considered few of essentials elements for the normal and healthy growth of apple trees which if present in higher concentration also supports production. Different factors are responsible for the uptake of elements in plants amongst which climate plays an important role (Sakalauskaite et al., 2008). According to the results mean value of Ca, Mg, Na and K varied between 28 --174.1µg/g; 16343.3--77813.3 µg/g; 916.57--1070.58 µg/g and 26231.3--28643.4 µg/g respectively. Values of Mg found to be less than that is required value for healthy growth (Table. 2). Average content for these nutrients was recorded as 94 µg/g for Ca, 37188.4 µg/g for Mg, 981.46 µg/g for Na and 27277.33µg/g for K (Fig. 5). Micro-topography also serves as an important environmental factor affecting soil conditions (Li *et al*., 2008).

Lead concentration was found little higher in the orchard soils in comparison to soil orchards of other parts of the world (Table 2). Heavy metals (Cu, Ni and Cr) were found below threshold levels so didn't contributed much to soil degradation (Table 2). Results showed that Pb content in soil ranged between 15.8--180.38 µg/g. The maximum value of Pb was found in orchard number 4 located near the road side and due to rapid development of the area receives much vehicular emissions. Soil Cd varied between 12.98--29.15 µg/g and had a mean value of 59.8 µg/g which was found raised in comparison to other studies attributed to waste dumping at site location which includes food items, paints and cigarettes wastes. Similarly mean values for Cu, Ni, Cr and Zn were 14.96 µg/g, 27.18µg/g, 0.29µg/g and 199.33 µg/g respectively (Fig. 6).

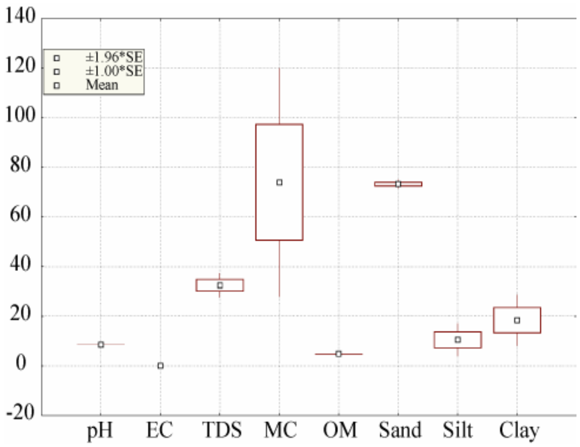

Fig. 4. Box and whisker plots showing concentrations of various physico-chemical parameters studied in the soils of *Malus domestica* (L.) *orchards.*

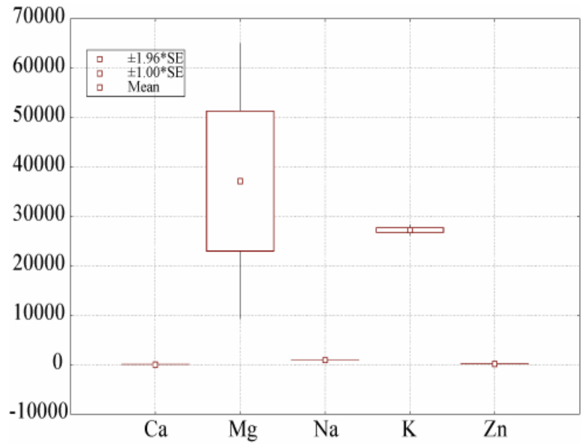

Fig. 5. Box and whisker plots showing concentrations of various nutrients studied in the soils of *Malus domestica* (L). *orchards*.

Table 2. Concentrations of metals of different soils of the world in comparison to the present study.

Soil quality standards	Pb (µg/g)	Cd (µg/g)	Cu (µg/g)	Ni (µg/g)	Cr (µg/g)	Zn (µg/g)
Canada	70	1.4	63	50	64	200
Australia	50	1.5	60	60	80	200
Current study	83.1	12.9	14.9	27.1	0.29	199

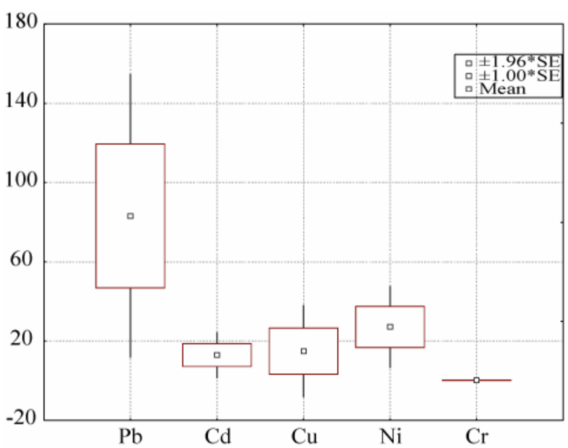

Fig. 6. Box and whisker plots showing concentrations of heavy metal content studied in the soils of *Mauls domestica* (L.) *orchards.*

In the present study, results present decline in apple production due to unusual seasonal variations, elongated summer period, unusual rain fall patterns. The most important contributor from the above mentioned factors was found to be the heavy snowfall in flower blooming period in year 2009 that bring about devastating and drastic change to the zero production level (Fig. 2). It brought frost to the vegetation and destroyed flowers completely which ultimately declined the fruit production. The major impacts of climate change in South Asia include the melting of glaciers in Himalayas and consequent increase in flooding which build up the pressure over the natural resources and a resulting stress over the environment, disease outbreak, impacts on soil fertility, which will end up in erosion and reduced crop growth (Ahmad *et al*., 2010). Unsustainable harvesting also results in gradual degradation of ecosystem 9 *Qin et al*., 2012). Therefore there is a need to launch awareness campaigns.

Questionnaire based data targeted the local farmers and served as the most vital source of primary information as they experienced the direct effects of changing weather patterns and climate change on apple production which in turn affects their livelihood. Questionnaire was based on 3 sections; structural variable section, key variable and interrelated questions. These consisted of both direct and indirect questions which elicited the respondent's utilization, knowledge, attitude and perception of the existing conditions of the orchards production concerned with a series of management and administrative issues. Key variable section comprises 13 questions which were to relate the decrease of apple production with climate change. In view of local farmers opinion 91% of them correlated declining production with the altered rainfall, snowfall, temperature patterns and daylight duration that year while rest of the 9% farmers did not agreed that climate change is responsible for decline in production. Most of the farmers (85%) were of the opinion that there is a strong need to consult relevant organization for better farming techniques to avoid any such unforeseen circumstances and weather pattern.

Being a developing country, proper management of the major producer areas of the important crops are lacking in Pakistan mainly due to inadequate funding and non-technical management. As a result these areas suffer from many issues of productivity loss of resources. The Kotli Satian area which is one of the potential producers of apple in Pakistan has faced the long term and short term effects of global warming on apple production. Average production during years 1980-1989 was found to be 2522 kg and during 1990-1999 it raised to 3411kg but during last ten years between 2000-2009 it declined to 2069 kg (Fig. 7). The case study served as an effort to help farmers by bringing awareness about the devastating effects of climate changes and encourage them for enhanced agricultural practices. As abrupt rainfall and temperature changes were found the major factors related directly in deteriorating the productivity level of apple.

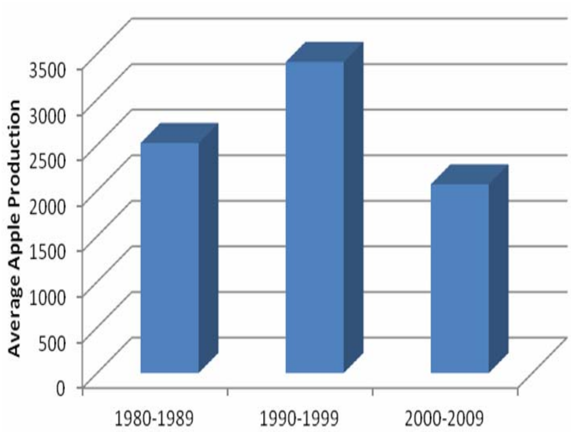

Fig. 7. Average Apple production during last three decades showing decline in last ten years.

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