WORLD ENVIRONMENT DAY
JUNE-2013

on the theme of
"THINK-EAT-SAVE"

Celebrated by
PAKISTAN ENGINEERING CONGRESS

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WORLD ENVIRONMENT DAY

JUNE-2013

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FOREWORD
BY
ENGR. CH. GHULAM HUSSAIN[1]
ON
WORLD ENVIROMENT DAY 5TH JUNE, 2013

This Publication of the Pakistan Engineering Congress comprises papers presented by engineers and scientists on the World Environment Day observed on June 5th, 2013 on the theme of **"THINK – EAT – SAVE"** as a campaign of save food initiative.

The authors in these papers have documented food loss and waste in various forms around the globe in general and Pakistan in particular. In these papers the causes of food losses and waste have been identified and mainly attributed to financial, managerial and technical limitations in harvesting techniques, storage, infrastructure, packaging and marketing systems. The devastating effects of polluted and contaminated water on food and environment have been thrashed out correctly for enhancing the awareness on this issue. The ways and strategies for transforming food waste into valuable resource and future food challenges have effectively been pointed out to overcome these global issues so that the food waste could be controlled and its hazardous impact on environment is prevented.

Almighty Allah gave us the gift of imagination to see better or worse. Its upto us to utilize this special gift for the mutual benefit of all of the earth's inhabitants and its environment so that we all have a better future on this planet. For maintaining a high standard of living for our future generation we have to stabilize the population growth. The importance of food and nutrition in human development is widely recognized in both high income and middle to low income countries. Malnutrition in all its forms amounts to an intolerable burden not only on national health systems but the entire cultural social and economic fabric of nations and is the greatest impediment to the fulfillment of human potential. Good nutrition improves productivity into intellectual capacity and social development for present and future generations.

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[1] Vice-President, Pakistan Engineering Congress

More than one third of all food produced for human consumption is wasted each year which could be used to feed hungry people. Food discarded could be another hazard in healthy environment. Food losses happen due to lack of knowledge of farmers and bulk quantity of food is wasted in various regions of the world due to unsustainable consumption behavior of the people. Food losses if prevented could help in poverty alleviation, food security and above all prevent adverse environmental impact of wastage.

The vast majority of world population growth is expected in the developing countries where food and water shortages are already high. The increasing demand for food due to population explosions and economic growth is pushing the prices of food up. By wasting less and feeding more we can protect our environment.

Food security and economic growth mutually interact and reinforce each other during the development process. Food security becomes a fundamental component of national security but unfortunately it is generally ignored in all developing countries. The path ways and strategic options to achieve food security have rightly been highlighted for a growing population in Pakistan.

Pragmatic suggestions have clearly been underlined by the contributing authors. All the well wishers and the stakeholders have to be proactive and should start ensuring the implementation of the suggested remedial measures such as development of infrastructure with sustainable technologies, investing in bio-security practices and bio-remediation techniques, improving storage facilities, installing of high efficiency irrigation system and the capacity building in various spheres. It is quite obvious that the large segment of population in Pakistan is suffering from food shortage both in urban and rural areas. Sustainable solution can play a vital role in preventing food losses, shortage and wastes. Pakistan being a developing country there is a dire need to improve harvest techniques, storage facilities, farmers education and to adopt an effective strategy for changing the consumer behavior of the general masses.

A Review of Global Food Security: Production, Wastage, Shortage and Solutions

Ms. Asifa Alam, Dr. Engr. Abdullah Yasar, Dr. Amtul Bari Tabinda[1]

Abstract

This review focuses on the food produced in the world, amount of food which is being lost every year in different regions of the world and its environmental impact, world food shortages and ways by which food losses can be prevented. At global level, around 1.3 billion tons of food is being lost or wasted every year. Main reason of food loss is inefficiencies in food production and processing procedures that reduces supplies, secondly significant food wastage occurs at consumers and sellers level. In developed world, the wastage is about 222 million tons per year which is equal to annual harvest in sub-Saharan Africa and this is due to unsustainable consumption patterns. In 2011, FAO estimates that there are 925 million people in the world which suffered hunger. In developing world, there is need to improve harvest techniques, storage facilities and farmer education whereas, in developed countries, there is a need to change the consumer behaviors. An accurate strategy is needed to create it easy to behave sustainably. Awareness raising campaigns can provide knowledge to people about reducing food foot-print and sustainable consumption. Food waste has a venomous impact on environment in the form of CO_2 and CH_4 emissions. Best food management practices can prevent these emissions.

Introduction

World Food Production

Production volumes of all commodities in different regions of the world are depicted in Figure 1 (Gustavsson 2011). In Industrialized Asia, meat production was conquered by pig, which is around 46 million tons and chicken production is almost 12 million tons. Meat in developing regions was subjugated by cattle (around 15 million) and chicken production is around 17 million tons. Fruits and vegetable production is high (630 million tons) in industrialized Asia. Cereal production is

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prominent in South and Southeast Asia (600 million tons) followed by North America, Oceania (490 million tons) and Industrialized Asia (480 million tons). Oil crop production is well known in developed countries such as North America (100 million tons). Dairy commodities are produced in great amount in Europe (250 million tons) followed by South and Southeast Asia (180 million tons).

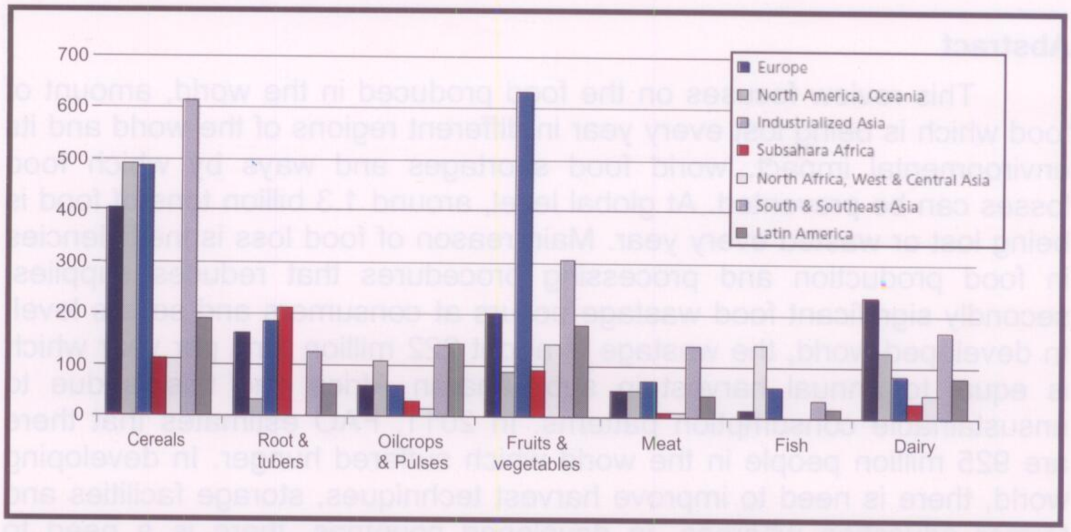

Figure 1: Production values (in million tons) of each commodity in world regions (Source Gustavsson, 2011)

Global Food Wastages

The food wastage in developed world is almost 222 million tons per year which is equal to annual harvest in sub-Saharan Africa. Main reason of food losses is inefficiencies in food production and processing procedures that reduce supplies whereas food wastes when consumers and sellers throw food away. Food losses at each stage of food life cycle starts from harvesting to final consumption. Diseases, poor weather conditions and infestations cause food losses at cultivation and production stage. After harvesting, further losses happen due to processing, storage and transportation techniques. During processing of food, wastes occur due to limitations of technologies and techniques. Packaging processes also matters in food wastes. Next stage of food waste is distribution processes, large amount of food remained unsold due to marketing strategies, quality standards and logistical aspects. Restaurant, domestic and industry consumption is the last stage. Waste at this stage is due to surplus of purchased food and unsustainable consuming behavior. (Figure 2)

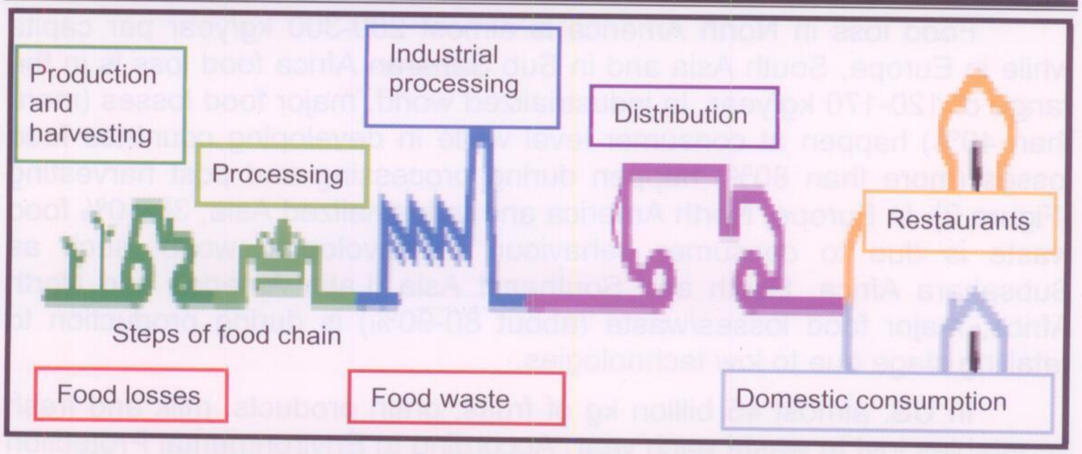

Figure 2: Stages of food losses and waste along food chain (Source: BCFN elaboration 2012)

Following are the causes of food waste and losses:

- When production surpasses demand cause food loss in industrialized world.
- Premature harvesting also leads to food lost in developing world.
- In industrialized world, a person's unsustainable consuming behavior cause high food loss.
- In developing world, lack of storage capacities and poor infrastructure cause food loss in bulk quantity (Schneider, 2008).

At global level, around 1.3 billion tons of food is lost or wasted per year and it accounts the one-third of total food production for people utilization (Congress, 2011)

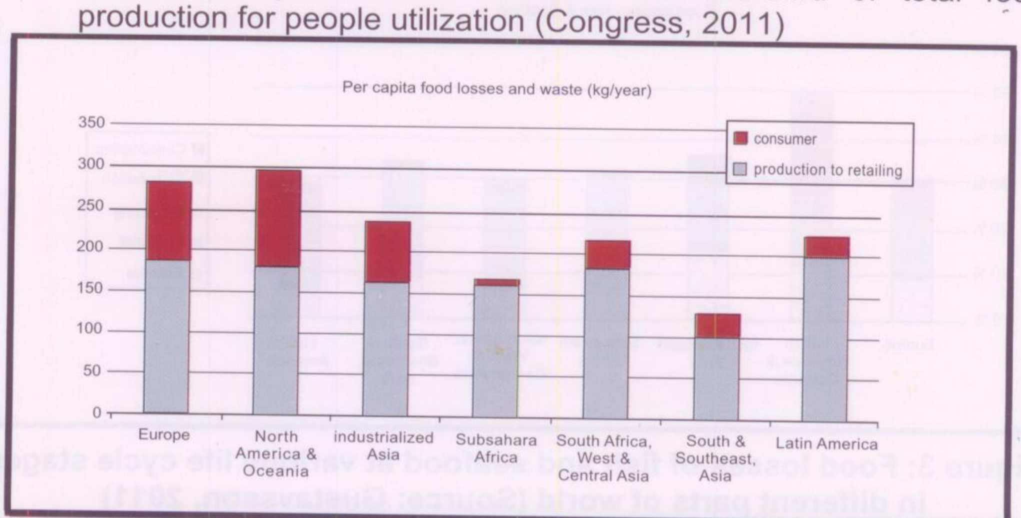

Figure 2(a): Food losses and waste per capita, in different world's regions at pre-consumption and consumption stages (Source: Gustavsson, 2011)

Food loss in North America is almost 280-300 kg/year per capita while in Europe, South Asia and in Sub Saharan Africa food loss is in the range of 120-170 kg/year. In industrialized world, major food losses (more than 40%) happen at consumer level while in developing countries food losses (more than 80%) happen during processing and post harvesting (Figure 2). In Europe, North America and Industrialized Asia, 30-40% food waste is due to consumer behaviour. In devoloping world, such as Subsahara Africa, South and Southeast Asia, Latin America and North Africa, major food losses/waste (about 80-90%) is during production to retailing stage due to low technologies.

In US, almost 45 billion kg of fruits, grain products, milk and fresh vegetables lost to waste each year. According to Environmental Protection Agency (EPA), its disposal cost is about 1 billion dollars. Annual food waste production is 20 million ton in UK and this one day's waste is equal to 60 million people lunch. Each ton of food waste leads to 4.5 ton of CO_2 emissions. The food wastes are produced greatly by dairy, meat, fruit and vegetable oil, fermentation and seafood industries (Kosseva, 2009).

Consumer household waste includes huge amount of acquired fish and seafood. Figure 3 illustrates losses in seafood production and fish and these losses are noteworthy due to discarded rate of 9-15 % of marine catches in industrialized countries. The most recent assessment shows that weighted global discard ratio is 8% (Kelleher, 2005).

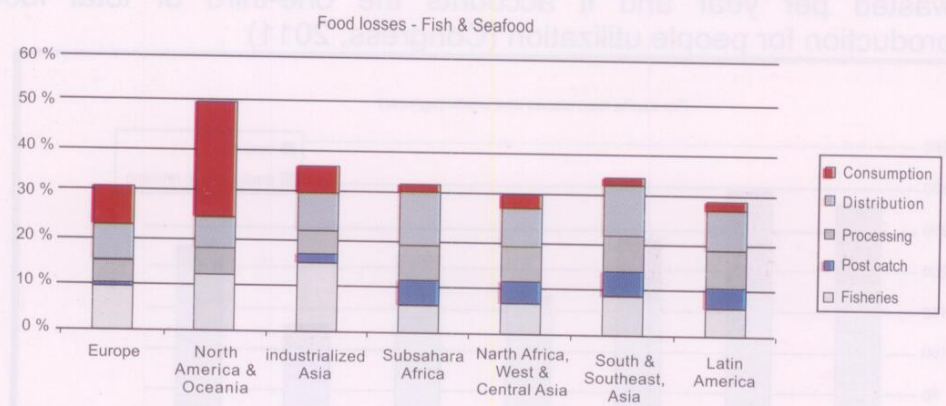

Figure 3: Food losses of fish and seafood at various life cycle stages in different parts of world (Source: Gustavsson, 2011)

Impact of food waste

Food waste emits CO_2 and CH_4 in environment from the decomposition of food, which affects global climate change and it leads to the overuse of freshwater and overexploitation of fossil fuels (Hall et al. 2009). Food waste at landfill site degrades the soil and causes gas emissions and these are the main anthropogenic cause of methane emission (Figure 4). It was predicted that Asia experienced the great increase in food waste from 278 to 426g/kg. If these present management trends are continued, landfill food waste would increase global methane emissions from 34 to 48 g/kg and it raises 8 to 10% world emissions from anthropogenic sources (Onay et al 2010). Economic impacts include cost or value of the food being waste and cost on the negative externality produced by food wastes.

Figure 4: Food waste dumping, potential to gaseous emissions from decomposition

World food shortage

World hunger is mounting day by day. It is becoming more complicated for many countries to achieve the target of World Food Summit (WFS) to halve the number of malnourished citizens of world in 2015. In recent years 2003, 2005, 2007, swift increase in unceasing hunger is experienced. Estimates of FAOs illustrated the fact that 75 million people were undernourished in 2007 comparative to 2003-05 (State, 2008). Data of recent report of FAO shows that there are 925 million people in the world which suffered hunger (FAO, 2011) (Figure 5).

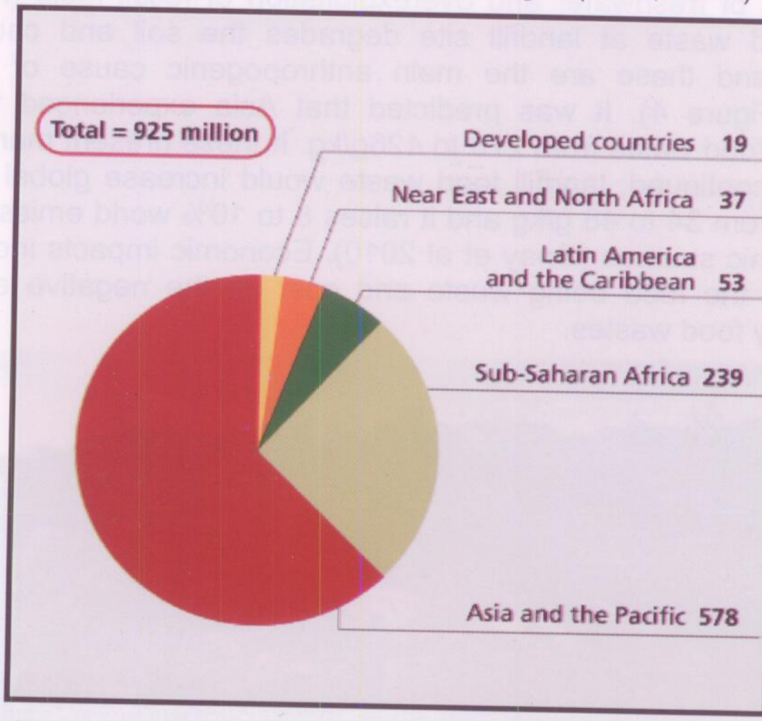

Figure 5: Number of hungry people in the world (Source FAO, 2011)

Various aspects are responsible for world hunger such as high prices of food that leads to million of people into food insecurity, unsustainable trend of food utilization in developed world, exacerbate circumstances for numerous people who were already food-insecure, and it threatens the global food security in long-term. This is a worldwide challenge and it requires an inclusive response (State, 2008). The global food scarcity may cause lower trade barriers and novelty that could raise farm output (Hamm, 2008). Small number of people will be able to access food in developing countries and it is extremely serious risk (Katz, 2008). Food shortage, food poverty and food scarcity are three main factors to estimate world food situation and to analyze the number of hunger affected people (Uvin, 1994).

Reduction in food losses

It is crucial to prevent the food losses and food wastes because these may lead to world food shortages and food wastes have hazardous impact on environment.

Food centers or regional aggregation could enhance coordination facilities and offer systematic and social change. There is a mounting concern in food hubs as a way to removing food hungers, improving infrastructure, invigorating local economies, giving low carbon footprint to all communities, rising farm viability. But the food system is highly complicated, economic and social objectives can seem at odds, and several food hubs springing up may seem dizzying (Fisk, Barham, Carmody, & Collier, 2011).

In developing countries, increase in investment and efficient food production can reduce food loss.

Education and awareness about sustainable consumption, reducing footprint, consequences of food waste can reduce the food losses in developed and developing regions. Consumer behavior is crucial factor and it has a great impact on environment. People choices about the product and services have a significant impact on environment in a direct and indirect way (Jackson, 2005).

Ecological citizenship may be a crucial inspiring force for sustainable consumption behavior. Sustainable consumption can be promoted by shaping the situations for consumption (Seyfang, 2006).

Conclusion

Various food commodities are produced, consumed and transferred in several regions of world as food is a major source and energy demanding product. Food losses happen in food chain due to lack of knowledge of farmers and bulk quantity of food is wasted in various regions of world due to unsustainable consumption behavior of people. Food waste has a venomous impact on environment in the form of CO_2 and methane emissions. For the prevention of these emissions, best food waste management practices are needed. As world hunger is rising bit by bit and it seems more challenging to halve the number of hungry and malnourished people by 2050 as by the goal of World Food Summit (WFS). Sustainable solutions can play a crucial role in preventing food losses, shortages and wastes. In developing world, there is need to improve harvest techniques, storage facilities and farmer education whereas there is need to change the consumer behaviors in developed countries. A rigorous strategy is needed to formulate it easy to behave sustainably. Food losses should be prevented because it's a crucial factor not only in saving resources but also in reducing environmental impact during production, transport and waste management.

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POPULATION EXPLOSION AND FOOD WASTE

By
Mrs. SHAHIDA SALEEM[1]

Population Explosion and Food Waste

The rapid increase in population over the past three centuries has raised concerns that the planet Earth may not be able to sustain a larger number of its inhabitants. More than two hundred years ago a British economist, Thomas Malthus, predicted that mankind would outgrow its available resources since a finite amount of land was incapable of supporting an endlessly increasing number of people. He also asserted that inevitable over population would lead to starvation, pestilence and war.

Now, with two centuries of hindsight it seems fair to ask washe right? All we have to do is to look at some parts of South-east Asia and Sub-Saharan Africa. Something like a billion people go to bed without food every night and more than 3 billion people are malnourished. Over 60% of the malnourished people are in Asia and a quarter in Africa. However, the proportion of people who are hungry is greater in Africa (33%) than in Asia (16%) (World Health Organization).

1. HISTORICAL OVERVIEW

Until recently the growth of population was slow and variable. A pronounced expansion began with the advent of the industrial Revolution about two centuries ago.

[1] Professor of Economics

Table no. 1 WORLD POPULATION

YEAR	POPULATION (Billions)	Years elapsed between milestones
1804	1	
1927	2	123
1959	3	32
1974	4	15
1987	5	13
1999	6	12
2011	6+	
2012	7	
2013	7+	
2050 Estimated	9.3 expected to be 10.1 by 2100	

Data source: UN Population Division and United States Census Bureau.

Whereas tens of thousands of years passed before the human species reached the mark of one billion, it took only 123, 33, 15, 13 and 12years to add each succeeding billion. In fact, world population has exploded over the past century growing from less than 2 billion to 7 billion people in 2012. This accelerated rate of growth is what is meant by the term population explosion, caused by such factors as a decline in the infant mortality rate and an increase in life expectancy.

Population growth is strongly linked to the economic stability of a country. The developed countries of the Western World are not facing this problem. It is a serious issue in the developing countries like China, India, Pakistan, Indonesia, and Bangladesh who are major contributors towards the world population. However with growing wealth and improvement in their economic conditions, population growth rates are slowing down in these countries.

Table.2 Population Growth Rate (%)

USA	**0.97**
UK	**0.48**
China	**0.4**
India	**1.4**
Indonesia	**1.16**
Pakistan	**1.84**
Bangladesh	**1.67**
World	**1.17**

Source: UN World Population Report (2005-2010).

In Africa the growth rate of population has been alarmingly high that is between 2.8% and 3.4% per annum. The largest population increase, however, is projected to occur in Asia, particularly in China, India and Southeast Asia, accounting for about 60% or more of the world population by 2050(UN Population Division, 2007).

1. CONSEQUENCES OF OVERPOPULATION

Over population is giving rise to many environmental problems like rising levels of atmospheric carbon dioxide, global warming and pollution. The resources are depleting at an alarming rate. Even in the developed world resources such as fisheries, ground water, natural gas, coal and oil reserves are being exhausted at a fast rate. Increased demand for land, fresh water, starvation, widespread poverty, unemployment and deteriorating living conditions too are associated with population expansion. However the most challenging problem is that of ever increasing demand for food and the consequent rise in food prices, making it difficult for the poor to survive.

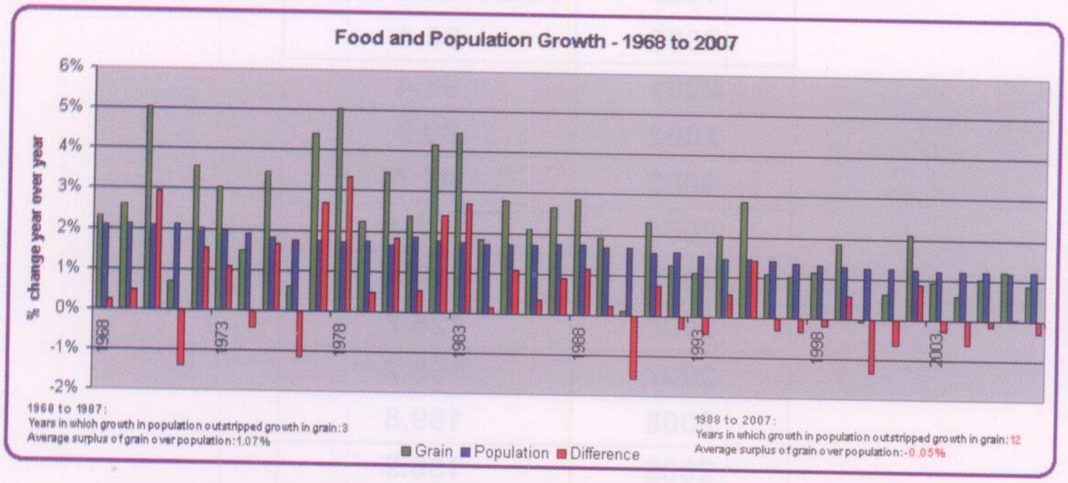
2.1 WORLD FOOD DEMAND

The world food demand has increased tremendously due to the growing world population, rising world incomes and dietary changes. Patterns of food consumption are becoming more similar throughout the world, shifting towards higher quality and more expensive foods such as meat and dairy products. Meat production is particularly demanding in terms of energy, cereals and water. Nearly half of the world's cereals are being used for animal feed. Biofuel production in Western Europe and America is also consuming large amounts of food grains and sugarcane which otherwise could be made available for human consumption.

The developing countries are becoming increasingly more dependent on cereals, meat, and milk imports since their production is not keeping pace with demand. As living conditions improve in these countries and poverty rates decline, the demand for food is expected to increase further. The United Nations has predicted that up to 70% (80% in the developing countries) more food will be needed to feed the 9.3 billion people expected by the year 2050.

2.2 WORLD FOOD PRODUCTION AND SUPPLY

Global food production increased substantially over the past sixty years. In the early 1960's most nations were self-sufficient in food production, despite the fact that the world population was growing at an alarming rate of 2% per annum. The Green Revolution at that time brought about remarkable increases in crop production. Increased fertilizer application, and more water usage through irrigation have been responsible for over 70% of the crop yield increases in the past.



Fig, no. 1 Source: United Nations Food and Agricultural Organization.

The above figure shows that in the years from 1968 to 1987, growth in food production outstripped the global population growth. However, during the period 1988 to 2007, growth in food production fell below the growth in population. The average surplus of grains over population declined from 1.07% in 1968-1987 to 0.05% in 1988-2007. Globally the rate of growth in yields of the major cereal crops has been steadily declining, it dropped from 3.2% per year in 1960 to 1.5% in 2000 (FAO, 2009). Natural disasters and severe droughts in various parts of the world have been a major cause of the decline in food production. Global warming, crop intensity and urban sprawl have also affected agricultural production. Since the global food supply is failing to keep pace with the growing food demand, the world is experiencing food inflation.

Escalating food prices

The world food prices increased dramatically in 2007 and 2008, creating a global crisis and causing political, economic and social unrest in both the poor and the developed nations. The price spikes of 2008 pushed at least 100 million people into dire poverty. Inflation first rears its head in the poorest nations around the world hitting the poor hardest, making their lives even more miserable.

Table no. 3 FOOD PRICE INDEX (2002-2004=IOO)

Year	Food Price Index
2000	90.4
2001	93.4
2002	89.9
2003	97.7
2004	112.4
2005	117.3
2006	126.7
2007	158.7
2008	199.8
2009	156.9
2010	185.3
2011	227.6
2012	212.7
2013(March)	212.4

Source: UNFAO 2013.

(Food here consists of the average of five commodity groups namely meat, dairy products, cereals, sugar and oil & fat).

The table shows that after reaching the peak in 2008, prices fell down during the recession but started rising again in 2010 reaching the peak in 2012, at a level higher than the level reached in 2008. Due to global warming and extreme weather conditions, in 2012, there was a major decline in the yields of wheat, corn and soya beans pushing the food prices up (FAO). According to the World Bank large increases in biofuels production in the United States and Europe could also be a major reason behind the steep rise in global food prices.

Causes of food inflation

The rise in the food prices, leading to double-digit food inflation, can be attributed to the increase in oil prices which in turn caused general escalation in the costs of fertilizers, food transportation and industrial agriculture. The root cause may also be increased use of biofuels in developed countries and an increasing demand for a more varied diet across the world especially the expanding middleclass population of Asia.

Moreover, developing countries like India and Pakistan have some serious supply side issues like low electricity production, water scarcity, business unfriendly practices and market inefficiencies which do not allow production to increase. Enormous amount of food loss at the pre-harvest and post-harvest stages in developing countries has also played its role in pushing the prices up by causing a decline in the food supply.

The world now faces a threefold challenge: to match the rapidly changing demand for food from a larger and more affluent population to its supply; to do it in ways that are environmentally and socially sustainable; to ensure that the world's poorest people are no longer hungry. This requires radical changes in the way food is produced, stored, processed, distributed and consumed. Increases in production are now constrained, as never before, by the finite resources provided by the Earth's Lands, Oceans and atmosphere. So how can we produce more?

In the past new lands were brought under cultivation for increasing production. Now this is not possible. The planet has virtually no more arable land or fresh water to spare. Per capita cropland has fallen by more than half since 1960, and per capita production of grains, the basic food, has been falling worldwide for the past twenty years (World Watch Institute, 2013). Soil erosion, deteriorating rangelands, falling water tables, fresh water shortages, depleting fisheries, rising temperatures and droughts are making it difficult to expand food production fast enough to keep up with the growing demand.

The other alternative is to increase food supply by reducing food waste/loss and reducing demand by eating less and avoiding wasteful consumption. Developing habits to save food now could dramatically reduce the need for increased food production in the future.

3. FOOD WASTE AND LOSS

Worldwide, it is estimated that about one third of all food produced, worth around $1 trillion gets lost or wasted in production and consumption systems annually (FAO, 2011). According to a report of the Institute of Mechanical Engineers (UK) published in January 2013, the world is producing 4 billion metric tons of food annually of which 30 to 50% is wasted or lost every year. This figure does not reflect the fact that large amounts of land, water, fertilizers and energy have also been lost in the production of foodstuff which simply end up as waste. It is a big tragedy as according to FAO, just a quarter would suffice to feed the world's hungry.

3.1 DIFFERENCE BETWEEN FOOD WASTE AND FOOD LOSS

Food waste is the food which is fit for consumption but is discarded usually at the retail and consumer level. This is a major problem in industrialized countries where throwing away is cheaper than using and reusing it and consumers can afford to waste it. Food waste is mostly avoidable.

Food loss, on the other hand is the decrease in edible food mass at the production, post-harvest, processing and distribution stages in the food supply chain (FAO). Food loss is mostly unintentional.

3.2 CAUSES OF FOOD WASTE AND LOSS

In developed countries large quantities of food are wasted at a later stage in the food supply chain, mainly at the manufacturing and retail stages, because of inefficient practices, quality standards and confusion over date labels. However, substantial amount of food is also lost at the farm in the pre-harvest stage due to rejection by the buyers for their physical characteristics such as shape, size and appearance. Consumers waste food by throwing away edible food due to overbuying, inappropriate storage and preparing meals that are too large.

In developing countries 95% food loss takes place at the early stages of the food supply chain caused by financial, managerial and technical limitations in harvesting techniques; storage and cooling facilities; infrastructure; packaging and marketing systems (FAO). In addition uncertain weather conditions and natural disasters too have a role to play. Pre-harvest losses are due to insufficient Investment in bio security practices.

3.3 EXTENT OF FOOD WASTE AND LOSS

The per capita edible food production for human consumption, in Europe and North America is about 900 kg/ year, while in Sub-Saharan Africa and South/South-east Asia it is 460 kg/ year (FAO, 2011).

Table no. 4 Per Capita food waste and loss in different regions (kg/year)

	Production to retailing	Consumer level	Total
Europe	185	95	280
North America/Oceania	185	115	300
Sub-Saharan Africa	164	6	170
South/South-East Asia	109	11	120

Source: UNFAO, 2011.

Food is wasted throughout the food supply chain from initial agricultural production down to final household consumption. The World's biggest food wasters are Europe and North America.Per capita food waste by consumers in North America and Europe is between 95 kg and 115 kg a year, while in Sub-Saharan Africa, South and South-East Asia consumers throw away 6kg to 11kg a year.

Table no.5 Loss of Perishable Food

Food items	%age loss
Fruits, vegetables, Roots, and tubers	50
Sea food and Cereals	30
Meat and Dairy products	20

Source: UNFAO, 2011.

The above table shows that almost half of all harvested fruits, vegetables, roots and tubers are lost annually because of their perishable nature and public squeamishness over consuming food after its sell-by date. Next are sea food and cereals with losses of 30% and in case of meat and dairy products, losses are 20% per year. In industrialized countries food also gets lost when production exceeds demand.

According to an estimate of FAO, from 30% to 40% of the food produced, processed, transported, sold and taken home by consumers is thrown away in the UK and USA annually. In Japan household's and food industry discard nearly 30% of the edible food produced annually (Venkat, 2011). According to Stuart, (2009) 150 million tons of grains are lost post–harvest in developing countries, enough to feed all the hungry people six times over. In African countries post-harvest losses of food cereals are estimated at 25% of the total harvest while for fruits, vegetables and root crops, post-harvest losses can reach upto 50%. In India 21 million tons of wheat and 40% of fruits and vegetables are lost every year due to inadequate storage and distribution systems. In South-East Asia losses of rice range from 37% to 80% of the entire produce. In China the figure is close to 45% per year. North Korea and Indonesia lose up to 50% of rice annually post-harvest (Thomas, 2011)

Pre-harvest crop losses due to pests and diseases have also been estimated to be 40% per year (FAO).Bio security is a global problem because no one is unaffected. In Asia rats alone are responsible for 5% to 10% of pre-harvest annual rice losses. About 30% of pre-harvest losses of maize in Kenya are due to rat infestations (Meer berg, et. al 2009). In Australia 20% of wheat is lost to pathogens pre-harvest. Fungal pathogen black sigatoka has the potential to decimate world banana yield by up to 50%; generic weeds can reduce global wheat yield by 30% (Thomas, 2011).

3.4 IMPLICATIONS OF FOOD WASTE AND LOSS

There are significant financial, economic, environmental and social implications of food waste and loss. For producers it means reduction in income while for consumers it means higher than necessary spending. In rich countries people spend a smaller proportion of their income, almost 20%, on food hence they do not feel the pinch of it. For them the financial cost is very little. On the other hand, for the people of developing countries, financial costs are quite heavy as they spend a major portion of their income, about 60 to 80 percent, on food.

In terms of economic impacts food waste represent high waste management costs and money wasted given the considerable amount of edible food thrown away each year. Such waste management costs include the maintenance of landfills as well as transport costs and operation costs in the treatment plants. Since food production is resource intensive, food waste and loss also means squandering land, water, energy, labour, capital and all other resources required for food production.

Environmentally, food waste leads to wasteful use of chemicals such as fertilizers and pesticides; more fuel used for transportation; more rotting food creates more methane – one of the most harmful greenhouse gases that contributes to climate change. Methane is 23 times more potent than CO_2 as a greenhouse gas. In USA, organic waste is the second highest component of landfills which are the largest source of methane emission. In UK, animal digestive processes and manures release close to 40% of its methane emission (FAO). Once in the landfills food waste and loss makes significant contribution to global warming. It is important to realize that climate change and increased biofuel production represent major risks for long-term food security.

Wasting food has some social implications in terms of rising food inflation and international food shortages. Rising prices of food and food resources is putting a lot of pressure on the lower socio-economic groups in both the developed and the developing countries.

The real costs of food waste and loss include societal costs which include the cost of land degraded or deforested, the cost of water overused or polluted, cost of biodiversity put at risk, the cost of greenhouse gas emitted and the social cost of wasted human efforts and food insecurity.

4. CONCLUSIONS

The rapid growth in the world's population over the coming decades will present a great range of developmental challenges, including food security and environmental sustainability. The vast majority of world population growth is expected to place in the developing countries where food and water shortages are already very high. Rapidly increasing demand for food due to population expansion and economic growth is pushing the prices of food up because supply of food is not increasing fast enough to meet the growing world requirements. Although food production grew faster than the population growth over the past decades, it has now slowed down. Moreover, food waste and loss are also playing a major role in reducing the food supply.

Food waste takes place in the later stage of food supply chain while food loss takes place in the early stage of food supply chain. The study indicates that the world's biggest food wasters are the richest countries of the world, while in the developing countries due to the lack of proper transportation, storage, and marketing facilities, post-harvest food losses are enormous. It has also been observed that pre-harvest food losses occur in both the developed and the developing countries of the world because of insufficient investment in bio security.

In a world of rapidly growing population and scarce resources, food waste and loss can have devastating effects in the form of heavy financial, economic, environmental and social costs. Developing habits to save food now could dramatically reduce the need for increased food production in the future.

5. RECOMMENDATIONS

Most of the problems being faced by the world today, including food shortage, are due to the rapid increase in population. Investment in family planning and reproductive health and education of women can help in reducing population growth in areas where there is overpopulation, poverty and hunger. This will also help in reducing pressure on scarce land, water and energy resources required for producing agricultural commodities.

Currently more than one billion people are living in extreme poverty and a vast majority of these are in the rural areas of Sub-Saharan Africa and South-East Asia. Improving their livelihood through policies of economic growth based primarily on agriculture and non-farm rural activities must be given priority.

Yield per hectare in the developed countries is much higher as compared to the yields in the developing countries where food security is a major problem. Steps must be taken to close the yield gaps by raising the crop yields of the world's most inefficient farms to at least 95% of the best yields attained by the farmers in similar climates. Increasing agricultural productivity through the development of drought resistant crops and sustainable technologies will be crucial for meeting both the demands of a growing population and adapting to environments increasingly affected by global warming and climate change.

Although, the world is producing enough food to feed the entire population of the hunger stricken areas it is not distributed properly. International trade and communication networks must be used more efficiently to redistribute food from areas of surplus to areas of food deficits.

Food supply chain must be made more efficient through the development of infrastructure and sustainable technologies in the developing countries as food loss requires technical solutions. Food waste, on the other hand requires changing people's mindset and attitudes. Campaigns to raise awareness about the implications of over eating and food waste among the consumers of the industrialized countries are the need of the hour. A consortium of policy makers, representatives from industry, academia and the civil society could lead the way to design effective and practical actions to reduce food waste and loss.

A substantial share of the increasing food demand could also be met by introducing food energy efficiency, such as recycling of waste. With new technology, waste along the food supply chain could be used as a substitute for cereals in animal feed.

Pre-harvest food losses can be minimized by investing in biosecurity practices. In fact this is the area where the scientist and engineers can bring a new Green Revolution through research and development to overcome the problem of food shortage internationally. However, science and technology alone cannot guarantee food security maintaining good governance throughout the world is also crucial to success.

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FOOD SECURITY CHALLENGES IN PAKISTAN AND STRATEGIES TO OVERCOME

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Introduction:

Pakistan is a low income developing country. Agriculture is its most important sector due to its primary commitment of providing healthy food to its fast growing population. Although the rate of population increase has considerably slowed down from over 3% in 1980s to 2.09% in 2009-10, but it is still considered high. With the current rate of population growth, the population is expected to get doubled by 2050, making Pakistan 4th largest nation by 2050 from current status of 6th most populous state of the world. As regards the land resources in Pakistan, the total cultivated area has increased by just 40% during past 60 years, while there was more than 4 times increase in population with urban expansion of over seven-fold, resulting into mega-cities as well as rising population pressure on cultivated land. Despite that wheat production (a major food crop), has increased by five-fold and the country is still marginal importer of wheat. Tremendous efforts are needed to narrow the gap between population growth and domestic food production. Reducing poverty, hunger and food insecurity are essential part of Millennium Development Goals and are prerequisites for economic development. Food security and economic growth mutually interact and reinforce each other during the development process. A country which cannot produce the needed food quantity and has no resources or afford to buy food from the international market to meet its needs is not food sovereign state. Food security, thus, becomes a fundamental component of national security that which is generally ignored. Managing food security in Pakistan requires an understanding about the dimensions of food insecurity, what are the future challenges, and how agricultural policies affect food supply and incomes, the poor vulnerable in rural and urban areas, and what is required to be done. The

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main focus of this paper is to trace the pathways to achieve food security for a growing population in Pakistan.

Food Security:

Food security as a concept originated in the mid-1970s, in the discussions of international food problems at a time of global food crisis. The initial focus of attention was primarily on food supply problems & of assuring the availability and to some degree the price stability of basic foodstuffs at the international and national level. That supply side, international and institutional set of concerns reflected the changing organization of the global food economy that had precipitated the crisis. A process of international negotiation followed, leading to the World Food Conference of 1974, and a new set of institutional arrangements covering information, resources for promoting food security and forums for dialogue on policy issues. (ODI Briefing Paper, 1997)

The issues of famine, hunger and food crisis were also being extensively examined, following the events of the mid 1970s. The outcome was a redefinition of food security, which recognized that the behavior of potentially vulnerable and affected people was a critical aspect. A third, perhaps crucially important, factor in modifying views of food security was the evidence that the technical successes of the Green Revolution did not automatically and rapidly lead to dramatic reductions in poverty and levels of malnutrition.

Factors Affecting Food Security:

Poverty: Poor people lack access to sufficient resources to produce or buy quality food. Poor farmers may have very small farms, use less effective farming techniques, and/or be unable to afford fertilizers and labour-saving equipment, as of which limit food production. Often they cannot grow enough food for themselves and are even less able to generate income by selling excess to others. They may be forced onto less productive land which is prone to further environmental deterioration. Addressing poverty is important to ensure all people can afford sufficient food.

Health: Without sufficient calories and nutrients, the body slows down making it difficult to undertake the work needed to produce food. Without good health, the body is less able to make use of the food that is available. A hungry mother gives birth to an underweight baby, who then faces a future of stunted growth, frequent illness, learning disabilities, and reduced resistance to disease. Contaminated water and food can cause illness, nutrient loss and often death in children.

Water and Environment: Food production requires massive amounts of water. It takes one cubic metre (1000 litres) of water to produce one kilogram of wheat and 5,000 litres of water for one kilogram of rice. Producing sufficient food is directly related to having sufficient water. Increasing irrigation efficiency and limiting environment damage through salinization or reduced soil fertility is important for ongoing food availability. (Business Recorder, 2004)

Gender equity: Women play a vital role in providing food and nutrition for their families through their roles as food producers, processors, traders and income earners. Yet their lower social and economic status limits their access to education, training, land ownership, decision making and credit and consequently their ability to improve their access to and use of food. Food utilization can be enhanced by improving women's knowledge of nutrition and food safety and the prevention of illnesses.

Disasters and conflicts: Droughts, floods, cyclones and pests can quickly wipe out large quantities of food as it grows or is stored for later use or planting. Conflicts can also reduce or destroy food in production or storage. Farmers flee their fields for safety or become involved in the fighting. Previously productive land may be contaminated with explosive debris and need to be cleared before it can be used for food production again. Stored food, seeds and breeding livestock may be eaten or destroyed by soldiers or opposing groups leading to long-term food shortages.

Population and urbanization: Population growth increases the demand for food. With most productive land already in use there is pressure for this land to become increasingly productive. Expanding cities spread out across productive land, reducing the agricultural production including food production.

Trade: Many poor countries can produce staples more cheaply than rich nations but barriers to trade, such as distance from markets, quarantine regulations and tariffs make it difficult for them to compete in export markets against highly subsidised farmers in rich countries.

Components of food security:

Food security can be broadly divided into three main components namely; food availability (physical access to food), economic access to food, and equity of food distribution. According to some experts, however, the third component of food security is ‗effective food utilization or absorption'.

Food availability: Food availability is achieved when sufficient quantities of food are consistently available to all individuals. Sources of such a food supply could be household's own production, other domestic output, commercial imports or food assistance.

Access to food: Access to food is ensured when a household and all members of the household have enough (economic) resources to acquire food meeting the nutritional requirements and dietary needs of the household. Access is thus primarily a function of a household's income, its distribution within the household and the price of food, besides the physical aspect. Economic accessibility implies that personal or household financial costs associated with the acquisition of food, to meet dietary needs adequately, should be at such a level that the attainment and satisfaction of other basic needs are not threatened or compromised.

Food utilization or absorption: Food availability and economic access to food alone cannot ensure food security as proper food absorption is equally important. It has public health dimension and requires a diet providing sufficient energy and essential nutrients, along with access to potable water and adequate sanitation. Food absorption also depends on the knowledge within the household of food storage and processing techniques, basic principles of nutrition, proper child care and illness management. (SDPI, 2003)

Equity of food distribution: While there are sufficient resources in the world to provide food security for all, policy and behavioural changes are necessary to guarantee a fair share for all people, especially the poor. Equity is a major issue of concern related to food security, particularly in the context of Pakistan wherein inequity in land holdings and incomes is relatively high. There is a wide variation in income, human development as well as overall development across regions and provinces. Ethnic divide within some provinces makes the intra-provincial inequities more sensitive than they would have been in a homogenous set-up. (UNSFS, 2000)

Food Security Situation in Pakistan:

Agricultural production is the foundation of food availability, especially for calories and proteins. Adequate food supply at affordable prices is the cornerstone of food security policy of all nations of the world including Pakistan. Pakistan has made significant progress in terms of increasing supply of food items. Per capita availability of cereals increased from 120 kilograms in 1961 to 137 kilograms 1990-91 and further increased to 154 kilograms in 2008-9 (Ahmad et al. 2010), as shown in

Table 1, more than 80% of which is accounted for by wheat alone. The government of Pakistan has tried to maintain the availability at the level of 2400 calories per person per day since early 1990s, by increasing from a level of 1754 calories per person per day in 1961 (Table 2). However, daily average availability of calories per person in the country is substantially lower than the average of other developing and developed countries, by 10% and 26%, respectively. The changes overtime in the composition of food intake show a shrinking share of wheat in total calories available and a rising share from animals and other sources (Table 2), the share of wheat declined from 48% in 1990 to 38% in 2006, while the share of other cereals declined more prominently, from 20% in 1970 to 6% in 2006. The share of livestock products in calorie intake increased from 12% in 1970 to 18% in 2002, which marginally declined to 15% in 2006. The share of other items (vegetable oils, vegetables, fruits and sweeteners) has substantially increased from 20% in 1970 to 37% in 2006.

Table 1: Per Capita Availability of Food in Pakistan

Years	Per capita annual availability (kg/person/annum)							Per capita Daily avail.(kg)
	Food grains	Edible Oil /Veg.Ghee	Meat	Milk	Fruits	Vegetable	Total	
1990-91	137.44	9.99	13.90	60.93	47.73	23.49	293.4	804.06
1991-92	144.18	13.07	14.38	62.26	48.30	27.70	309.9	849.03
1992-93	149.93	12.50	15.48	63.09	49.06	24.45	314.51	861.68
1993-94	158.80	10.50	16.07	64.60	53.65	27.20	330.8	906.35
1994-95	138.20	12.19	16.51	66.07	55.63	28.84	317.45	869.72
1995-96	148.55	11.42	17.25	67.16	56.23	27.03	327.6	897.64
1996-97	153.95	10.46	17.87	68.58	55.34	29.98	336.1	921.06
1997-98	161.07	11.59	14.00	81.45	56.48	31.11	355.7	974.53
1998-99	167.25	12.38	14.13	81.72	56.07	29.04	360.5	987.93
1999-00	158.83	11.08	14.19	82.15	52.23	24.55	343.03	939.80
2000-01	136.51	11.48	14.42	82.92	51.31	28.65	325.2	891.20
2001-02	135.53	10.67	14.50	83.45	51.29	25.35	320.7	878.85
2002-03	142.38	10.77	14.65	84.28	50.36	26.65	329.0	901.61
2003-04	143.83	11.16	14.74	84.42	47.82	28.23	330.2	904.66
2004-05	142.58	12.35	15.19	85.50	52.64	26.17	334.4	916.23
2005-06	140.98	12.75	16.33	90.30	51.25	31.18	342.7	939.14
2006-07	144.79	12.81	16.70	94.54	50.04	29.79	348.6	955.26
2007-08	155.04	13.29	17.00	93.93	53.71	31.23	364.2	997.79
2008-09	153.99	13.45	17.50	94.81	52.88	24.06	356.6	977.22

(Farooq *et al.* (2009))

Domestic production, commercial imports, and food aid are the main constituents of food availability at the national level. The production of cereals and pulses increased more than 3.5-fold since the early 1960s. Nonetheless, Pakistan has been importing significant quantities of wheat, pulses and edible oil to meet the needs of its fast growing population. The share of imports in wheat consumption during the interval 1961-2006 has varied from 26% in 1961 to less than 1% in 2004. The huge deficit during the early 1960s was largely reduced during the 1970s as a result of the green revolution. The dependence on wheat imports, however, re-emerged later because of stagnation in wheat productivity. In contrast, Pakistan has been very successful in producing enough rice for domestic consumption and even generating a significant amount of exportable surplus (Ahmad, et al., 2010).

One of the important indicators of economic access to food is the proportion of people below the poverty line (FAO, 1998). The historical evidences show that poverty increased during the 1960s despite rapid economic growth, it declined during 1970 through 1987-88 in spite of the growth being relatively slower, the declining poverty trends got reversed in 1990s albeit with reasonable rate of economic growth, and during 2000s poverty continued to rise in the face of uncertain economic growth. Nevertheless, the daily average availability of calories per person progressively increased over the last five decade, even though this availability has not been consistently reflected in declining poverty.

Table 2: Per Capita Availability of Calories and shares of various sources

Year	Total		Wheat		Other Grains		Pulses		Animal		Others	
	Calories	%	Calories	%	Calories	%	Calories	%	Calories	%	Calories	%
1961	1754	100	742	42	342	19	114	6	260	15	296	17
1970	2203	100	984	45	438	20	77	3	257	12	447	20
1980	2124	100	967	46	304	14	49	2	261	12	543	26
1990	2410	100	1153	48	274	11	58	2	309	13	616	26
1995	2345	100	1048	45	212	9	59	3	353	15	673	29
2000	2447	100	1000	41	244	10	68	3	436	18	699	29
2001	2426	100	1000	41	256	11	58	2	436	18	676	28
2002	2419	100	999	41	275	11	59	2	437	18	649	27
2003	2320	100	945	41	108	5	61	3	322	14	886	37
2004	2231	100	897	40	107	5	62	3	321	14	844	38
2005	2271	100	914	40	108	5	63	3	325	14	861	38
2006	2423	100	930	38	110	6	65	3	330	15	888	37

(Ahmad *et al.* (2010))

Despite significant improvement in food supply in the aggregate, malnutrition is a widespread phenomenon in Pakistan. Rather, it has been argued that per capita food intake in the country has been higher than the recommended average at the national level. Nevertheless, one third of all pregnant women were malnourished and over 25% babies had low birth weight in 2001-2. Malnutrition was a major problem, responsible for more than 30% of all infant and child deaths in the country in 2001-02. The incidence of moderate to severe underweight, stunting, and wasting among children of less than 5 years of age was about 38%, 37% and 13% respectively in 2001-02 (Planning Commission and UNICEF, 2004). Malnourishment among mothers (as reflected in body mass index) was 21% in 2001-02 (Khan, 2003), while overall undernourishment was about 24% in 2004, which is not only worst in South Asia after Bangladesh, but this has been increasing over time (FAO, 2008). Micronutrient deficiency in Pakistan is pervasive in the country, which is regarded as ‗hidden hunger' reflecting a combination of dietary deficiency, poor maternal health and nutrition, high burden of morbidity and low micronutrient content of the soil especially for iodine and zinc (Government of Pakistan, 2010). The deficiency in most of these micronutrients affects the immunity, growth and mental development and may underlie the high burden of morbidity and mortality among women and children in Pakistan. This indicates that despite having sufficient food available at the national level, a large chunk of our population mostly the children and the women lack access to nutritiously balanced food.

The foregoing discussion highlights the fact that enhanced food security on its own cannot guarantee good nutrition status at the household level (Fullbrokk, 2010). Thus, greater food availability in Pakistan at the national level has not translated into actual increased consumption of calorie-rich food at the regional or household level reflecting reduced access to nutritious food and this could be due to worsening income and landholdings inequality in the country. A rising calorie-based poverty implies that most people had declining access to nutritious food. In addition, disparities in access to education and health may also be crucial. Therefore, simply emphasizing on increasing food supply cannot assure food security. In such circumstances the stable nutritious food supply and its distribution is considered to be crucial issue (Pinstrup-Andersen, 2009).

Nature of Future Food Insecurity:

In view of continuously rising population of Pakistan, the food demands of the country shall naturally increase. However, it is worth mentioning that future food demands would be different from today because of the factors like:

a) Increased proportion of older people due to age longevity;

b) Greater urbanization and emergence of big cities;

c) Changes in family composition and structure;

d) Changes in food consumption patterns and habits;

e) Prevalence of serious diseases like Cardiac, Diabetic and Hepatitis etc. and their special foods requirements; and

f) Rapid penetration of Super Markets and international Food Chains in developing countries.

To target such future diversions in food requirements, the major focus of the planners is to incentivize the agricultural production to future needs. Thus, production system needs to be channelized towards higher production of fruits, vegetables and other high value agricultural commodities. In Pakistan, 68% of the population earns their livelihood from agriculture sector. Livestock and crops sub-sectors contribute up to 28% and 24% towards rural households overall income, respectively. The non-farm enterprises, wages and services, remittances and other sources contribute 20%, 18%, 7%, and 3%, respectively. In rural Pakistan the economic access to food is mainly influenced by household level differences in land holding, education and employments. Decreasing size of land holdings (32% less than 1 ha and 24% less than 2 ha) besides inability of the economy to generate new employment and reduced additional employment capacity in the agriculture sector is not permitting to enhance productivity or incomes beyond a certain limits in future.

Even though food in Pakistan is predominantly produced in rural areas like other most of the developing countries, a majority of poor who are food insecure as well live in these areas—having lower economic access to food as compared to urban areas (World Bank, 2008; Staatz et al., 2009). Reliance on markets to obtain food for most of the food insecure people both in urban and rural areas is a common feature. The dependence of the urban poor on food markets is very well-known and documented, while reliance of the most of the rural food insecure has rarely been acknowledge—including landless, marginal farmers and majority of small farmers (Staatz et al., 2009). In addition to landless rural inhabitant (i.e. 45%), more than 30% of the cultivators are net buyers of food staples—accounting 62% of the overall rural population; who are partially or totally dependent on market for food needs (Ahmad, 2010).

Unfortunately, the government efforts in providing relief to consumers and the subsidy involved in food staples are rarely meant for these rural households. Furthermore, the access to the factors affecting the biological food absorption including sanitation, clean drinking water, and knowledge of the households regarding proper food storage, processing and basic nutrition, and health facilities, infrastructure etc. is very poor in rural areas. Particularly, the access to these indicators in food insecure rural areas is overwhelming shocking. Therefore, improving market infrastructure, arranging safety net programs, provision of better education and health facilities could be the central elements of any strategy to reduce chronic food insecurity in both the rural and urban areas in future.

Food Security Issues & Crop Damages:

Pakistan has suffered from unprecedented nationwide floods—flash, riverine and riverine delta type floods[1], spread over 160 thousand km^2 directly affecting more than 20 million people (United Nation's Office for the Coordination of Humanitarian Affairs (UN-OCHA) Satellite pictures, 2010); of which, 80% were directly dependent on agriculture. More than one million houses have been destroyed—about half of them are not even livable. More than 2 million ha of standing crops are affected to avarying degrees worth Rs.250 billion cash crops[2]. More than 1.2 million livestock and 6 million poultry heads worth billions of rupees have also been lost (MinLDD, 2010). About 0.5 million tons of wheat seed for coming rabi season stored at the farm households' level has been completely destroyed. The loss of cash crops, particularly cotton, will severely affect the textile/agro-based industry and the employment and export. Figure-1 below shows the percentage of damages occurred due to recent floods in different provinces of Pakistan.

[1] Flash floods had rapid onset and were highly destructive; riverine floods were slow in their onset but more people affected and it prolonged in time; the reverine delta floods are still persistence and water may stay there for months

[2] cotton crop followed by paddy and sugarcane

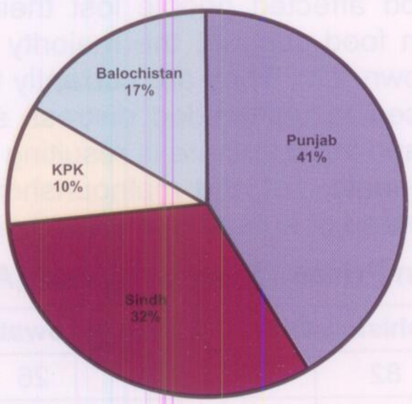

Figure-1: Percentage Crops damages by floods across provinces *(FAO presentation at Pakistan, dated 8-9-2010)*

The majority of the districts affected by the floods were already food insecure, and underdeveloped. Most of the schools and health facilities were either severely damaged or destroyed completely, limiting the provision of health services in flood affected areas for a longer time. Roads and market infrastructure have been severely damaged affecting the supply of essential items. The people most severely affected were predominantly marginal farmers, small and unskilled workers. Table-3 shows the details of the areas suffered from agriculture damages by recent floods.

Table -3: Agricultural Damages Caused by Floods

Province	Severe affected (>60%)	Moderate affected (30–60%)
KPK	Swat, Charsadda, Nowshehra, Upper Dir, Kohistan, Shangla, Tank and D.I.	Rest of Khyber Pakhtunkhwa
Punjab	Muzaffargarh, Mianwali, Rajanpur, D.G. Khan and Layyah	Bhakkar, Khushab and Multan
Sindh	Khairpur, Shikarpur, Dadu, Larkana, Thatta, Jacob abad, Kashmore, Sukkur, Ghotki and	Qambar Shahdadkot, Sukkur, Jamshoro, Tando Allahyar and Hyderabad
Balochistan	Kohlu, Sibbi, Jafar abad, Nasir abad, Barkhan	Rest of Balochistan

(FAO Presentation at Pakistan, dated 8-9-2010)

Most of the flood affected people lost their entire livelihood and currently dependent on food support, the majority of them will take long time to stand on their own feet. They are currently facing high food prices (Table 4) and are forced to unintended distress sale of animals at low prices. Loss in assets and infrastructure is resulting into un-acceptably low food intake, and inadequate diet and malnourishment of children. There are fears of rampant spread of human and animal diseases.

Table 4: Increases in Prices (%) after Floods (August & July 2010)

Commodity/ District	Kohistan	Dir	Mansehra	Swat	Kamber	Hyderabad
Wheat Flour	82	33	10	26	7	6
Broken Basmati Rice	87	--	7	33	-10	10
IRRI6-Rice	--	25	6	38	12	19
Split peas	22	18	22	31	--	--
Edible oil	--	11	22	17	--	--
Pakwan Ghee	9	16	17	18	--	--
Dalda Ghee	--	9	5	--	--	--
Sugar	43	16	8	14	13	22
Onion	--	--	--	--	41	25
Chicken	--	--	--	--	65	69
Beef	--	--	--	--	9	25
Mutton	--	--	--	--	8	13

(WFP (2010))

This implies that in the near future, food security issues shall be more serious in the country especially in flood affected areas in general and in poor food insecure districts in particular. That may result into further rise in food prices. Maplecroft (2010) has recently computed food security risk index and ranked Pakistan at number 30, high risk among 163 countries, rank 1 being at the extreme risk which is Afghanistan.

Future Challenges and strategic options:

The supply-side and demand-side issues of food security are the future challenges in the developing countries. Therefore, both challenges need to be addressed to ease food insecurity. Pakistan faces both of these challenges i.e. loose of food production potential, and access to food is also becoming a serious threat because of high incidence of poverty both in urban and in rural areas. Government of Pakistan is mainly focusing on urban areas from food security perspective. It is difficult to effectively address both of these challenges simultaneously. Pakistan has enormous potential to further develop its agriculture sector to which about 2/3rd of country's population is directly or indirectly depends for livelihood.

Pakistan has to adapt three-prong strategy i.e. develop farm and non-farm sectors as well as reducing polarization from within the agriculture sector by either helping the inefficient farmer to approach the frontier or helping them to find alternative livelihood in the non-farm sector if so developed.

If population growth continues at the present rate, Pakistan needs to enhance its food production for growing population with some modest surpluses for export. The fact is that to achieve this substantial increase in crop productivity is to be targeted using lesser land and water resources than are available for agriculture today. In order to achieve milestones agriculture must be maintained at a growth rate of more than 5% in order to ensure a rapid growth of national income, attaining macroeconomic stability, effective employment of growing labor force, securing improvement in distributive justice and a reduction in rural poverty in Pakistan.

A) Agriculture Growth

The major factors that influence the supply side of food are as follows;

1) *Higher use of conventional inputs:* Two major inputs in agriculture are land and water. The potential of allocating more of these towards agriculture is limited. Both of these resources are facing declining trend in supply caused either by land degradation or due to fast and unplanned expansion of cities. The chances for bringing unused or marginal lands under cultivation are remote and uncertain because of the following reasons;

- The amount of such land to be used is disputed
- The quality of such lands is poor and the investment to increase productivity in these lands may be uneconomical and unsustainable

The intensive use of land is another source of increasing agricultural output that too has reached even in the vicinity of 200% in certain irrigated areas indicating no chance of going beyond that. Similarly, the use of inputs like fertilizers and pesticides cannot be increased beyond certain limits because of national health and environmental concerns.

Furthermore, due to increasing prices of fertilizer, energy and declining water availability the already declining rate of growth in use of chemicals has turned into negative in recent years. Therefore, alternative sources of nutrients would have to be explored and popularized. The use of biocides is observed to be declining in many countries and only few countries are returning to organic farming. The other inputs include farm machinery i.e. tube-wells, tractors and implements, the supply of which once increased significantly is now facing the rate of change in growth on the decline. The available farm machinery is more suited to large farms, and thus the farm machinery research has to be redirected to explore and improvise mechanization suited to small farmers. The machines required for harvesting and post-harvest handling and small scale value addition are either not developed or faulty or if developed could not be passed on to the end users.

As regards the farm size, Pakistan has a highly skewed distribution of farm lands. In 2000, about 58% of total farms were smaller than 5 acres in size cultivating only 16% of total farm area. In contrast, only 6% farms having more than 25 acres of land were operating 32% of the total cultivated area. The situation in some provinces is rather more serious. Basically the ownership of this major factor of production determines the access to input and output markets. Therefore, the benefits of agricultural development are also shared rather more unequally. The poor small farmers use 30% to 50% less of various factors of production than the use at the rich farmers— leading to lower land productivity, greater poverty and food insecurity. All inputs combined have been contributing towards agricultural output growth ranging from 25-50% during 1990s in Punjab (Ahmad, 2003 and Ali and Byerlee, 2000). The above discussion highlights that there are only limited chances to increase the use of inputs in future and as a result increase the agricultural output—approaching upper bound through these resources.

2) *Total factor productivity (TFP):* It refers to shifting of the production limits upwards in case of progress, and downwards as a result of regress. Research and development (R&D) efforts, flow of information, better infrastructure, availability of funds and farmers' managerial capabilities are the prime movers of TFP. Empirical studies show that the TFP estimates differ widely and range from 0.37% to 2.3% dominating the share of TFP in output growth. Different studies have also shown the signs of declining TFP growth rates because of deteriorating land and water resources (Ahmad, 2003; Ali and Byerlee, 2000). There is strong empirical evidence that high levels of research and development (R&D) investments lead to

high productivity and eventually to increased economic performance. A strong relationship between agricultural output and outlays on agricultural research and extension exists in Pakistan and about 32 percent rate of returns on such investment has been observed (Khan and Akbari, 1986). Another recent study by Kiani et al. (2008) found that investment in agricultural research resulted in attractive returns in Pakistan ranging from 49-78% including highest returns of 57-88% in Punjab province followed by that in Sindh (24-48%). While R&D activities are important, these must be supported by favorable policy instruments, human resource development, necessary physical and institutional infrastructure etc.

3) *Targeted Conversions and Institutional Setup:* The third major factor that could be instrumental for agricultural growth is the policy targeted institutional changes including agricultural extension, education and credit, and improvement in the functioning of input and output markets (Saris, 2001). The existing institutions have further deteriorated the disparity between the rich/large and the poor/small farmers in rural Pakistan by offering greater access to influential and well-off farmers. Moreover, the agricultural price policies in Pakistan remained anti-producers and tended to slow down the growth. Under the Structural Adjustment and Stabilization Programs (SAP) the government of Pakistan removed all the subsidies during the 1990s resulting into many fold increase in input prices and thus greater cost of production— squeezing the profitability of the sector in general and of poor farmers in particular. While implementing the directives from International Financial Institutions (IFIs), the state's role was quickly reduced/ withdrawn without redirecting enhanced public sector focus on rural development to neutralize the policy effects on agriculture. The negative effects became more pronounced when the private sector investments lagged behind as well.

B) Strategic options to overcome Food Insecurity

The major hindrance in the way of achieving food security in Pakistan is the high levels of poverty, and thus reduction in poverty is a most powerful tool to improve food security that can be achieved through equitable economic growth. There are various ways to achieve pro-poor growth i.e. 1) by enabling the poor to participate in the growth process and increasing their access financial and productive resources and providing them physical and market infrastructure; 2) investing in the human capital of the poor— provision of health and education that enables them to take advantage of new opportunities; and 3) investing in the social capital of the poor i.e. network, norms, and trust among members of communities that help coordinate and cooperate for members' mutual benefit in the community. In Pakistan most of the poor live in rural areas and are directly or indirectly dependent on performance of the agriculture sector. Besides improving food security of urban population, food security of rural households can be improved by increasing agricultural productivity.

Pakistan is a low income developing country and agriculture is its most important sector due to its primary commitment of providing healthy food to her fast growing population. In Pakistan, the total cultivated area has increased by just 40% during past 60 years, while there was more than 4 times increase in population with urban expansion of over seven-fold thus resulting into mega-cities as well as rising population pressure on cultivated land. Despite that wheat production has increased by five-fold, the country is still marginal importer of wheat. Tremendous efforts are needed to narrow the gap between population growth and domestic food production. Managing food security in Pakistan requires an understanding about how agricultural policies affect food supply and incomes, the poor vulnerable in rural and urban areas, and how this burden is transferred to other sectors.

Food security is a three dimensions subject abridging adequacy of food supply, access to food, and equity of food distribution. All these dimensions require special interventions and enabling environment for ensuring household food security. Following are the strategic options recommended to reduce food insecurity in Pakistan;

- Sustainable and efficient utilization of the natural resources (like Land & Water).
- Proper application of physical inputs.
- Productivity enhancement of major food crops (i.e. Wheat, Rice, Maize, Oil Seed)
- Identification and targeting the food insecure people.
- Diversification of on-farm and off-farm income generation activities.
- Stabilization of input and output prices.
- Distribution of land and access to the resources and inputs.
- Gender inequity.
- Skill development and exposure to the development.
- Improving the nutritional aspects of food.

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NATURAL SOLUTION TO THE WATER POLLUTION OF RIVER RAVI

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Abstract

Water is a precious entity and clean water is the basic right of every human being. Pakistan is one of those countries which are having largest irrigation system. Because of ignorance and mismanagement of the water resources, unfortunately Pakistan is standing in the list of highly water stressed countries (<1066 m^3/capita)[3] and is going down (<1000 m^3/capita)[4] in the coming few years.

The River Ravi is considered the most polluted river of the country. This river water is continuously being polluted by human activities and this polluted water disturbs the aquatic life as well as our food chain. This study was conducted on the compilation of previous literature regarding the major factors which are polluting the River Ravi and a prospective solution has been suggested for the pollution abatement of the River. This report also recommends that the initiative taken by the River Ravi Commission (RRC) should be endorsed and implemented. The bio-remediation techniques should also be applied on the effluents drains in order to reduce the metal contamination and pollution loading. These kinds of initiatives will be very helpful for saving our food chain.

1. Introduction

Pakistan is having the largest contiguous irrigation system of the world. Because of a number of factors per capita consumption of fresh

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[3] Ahmad, S. & ADB, "Present Situation and Future Strategy", National Seminar on Water Conservation, PARC, PMPIU, MoW & P, 2009

[4] Briscoe, J. and Qamar, U., Pakistan's Water Economy: Running Dry (World Bank/Oxford University Press, 2006)

water has been reduced approximately from 5600 m^3 to 1000 m^3.[1] It was reported in different literature that the water availability in Pakistan is going down day by day. Because of mismanagement of country's water resources, Pakistan stands on the 7th place among the top ten "water insecure" countries of the world.[2] In 2005 water inflow for irrigation was declined from 172.8 Billion m^3 (140 MAF) in 1980s to an average of 123.4 Billion m^3 (100 MAF).[3] Until 1988 the groundwater recharge was found 41 MAF by public and private tube wells[4] but now the groundwater recharge has been reduced because of over abstraction.

The River Ravi is the smallest of the five main Eastern tributaries of the River Indus. It starts from glacier fields at Bara Bhangal, Himachal Pardesh, India and enters Pakistan at the Shakargarh Tehsil of District Sialkot before flowing past the city of Lahore and ends into the River Chenab. The total length of the River Ravi is 894 kilometers and it has a catchment area of 39,680 sq. kilometers.[5,6] The water level of the River Ravi has been reduced after the construction of Thein Dam due to which the recharge of the Lahore city has reduced day by day.[7] The water flow in the river Ravi varies throughout the year. The river Ravi has the following head works structures in India and Pakistan;

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[3] Yasar A., Fawad A., Fateha A., Amna I. and Zainab R. 2010. River Ravi Potentials, Pollution and Solutions: An Overview. Pakistan Engineering Congress: 39-48.

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[5] Fahlbusch, H., Schultz, B. and Thatte, C.D. 2004. The Indus Basin: History of Irrigation, Drainage and Flood Management, Introduction, International Commission on Irrigation and Drainage:1—17.

[6] Basharat, M. and Rizvi, S.A. 2011. Groundwater extraction and wastewater disposal regulation- Is Lahore aqifer at stake with as usual approach?. World Water Day. Pakistan Engineering Congress: 135—151.

[7] Alam, A.R. and PILA. 2012. A Writ petition before Lahore High Court under article 199 of Constitution of Islamic republic of Pakistan 1973, on saving ecology of river Ravi. LHC. W.P.No. 9137.

1. Thein dam, located at 101 km upstream of Jassar bridge, with a live storage capacity of 2,343 MCM (1.9 MAF).
2. Madhopur Headworks, located at 81 km upstream of Jassar bridge.
3. In Pakistan Balloki barrage, located at 160 km downstream of Jassar bridge.
4. Sidhnai Barrage at 200 Km downstream of Balloki Barrage

Past flood records by Provincial Irrigation Department (PID) showed that at Shahdara bridge the maximum flood recorded was 16,310 m3/s (576,000 cusecs) in year 1988.[1] The Average Annual Flow of the River Ravi into Pakistan between 1922 to 1961 was recorded at 7 million acre feet ("MAF").

	
Figure-1: The River Ravi	**Figure-2: River Ravi got dry**

After the signing of the Indus Waters Treaty, 1960 (the "Indus Waters Treaty"), rights to use the waters of the River Ravi were allocated to India and the average annual flow between 1985 to 1995 was recorded at 5 MAF. The flow in River Ravi ranges from 549 cusec (April) to 14,422 cusec (July) during the years 2001-2010 on an average.[2] Due to irrigation and hydropower diversions put in place in India, the average annual flow between 2000-2009 was recorded as 1.1 MAF. In order to overcome low flow issues such as water quality management, the Marala-Ravi ("MR") Link Canal, some 20 kilometres upstream of the Ravi Syphon and the Upper Chenab ("UC") and Qadirabad-Balloki ("QB") Link Canal, some 20

[1] WASA. 2012. Feasibility studies, planning and design of wastewater treatment plant for Mehmood Booti/ Salamat pura, Shadbagh and South-West sites, Lahore. National Engineering Services, Pakistan.

[2] Ibid

and 73 kilometres downstream, respectively, from the Ravi Siphon, discharge water from the River Chenab into the River Ravi.[1]

1.1. Quantification of Groundwater Extraction

Lahore city residing at the bank of the Ravi had huge groundwater aquifer because of Bari Doab surrounded by River Ravi, River Sutlej and BRB Canal. This water was extracted in huge amounts for public supply, industrial use and irrigation purposes. According to the study conducted by M/s NESPAK and M/s Binnie & partners in year 1991, water extraction in District Lahore was estimated to be 316 MGD while the WASA tube wells were abstracting about 220 MGD. According to JICA, total water abstraction in the six (6) towns of the WASA area was estimated to be 350 MGD for Jan-Feb, 2009. So because of over abstraction the declining in groundwater table was around 2.03 feet per year.

2. Water Quality of River Ravi

Pollution in the River Ravi is the highest compared to all the rivers in Pakistan. A number of studies have been conducted on the pollution of the River Ravi. The main pollution caused in the River Ravi in Pakistan is from Syphon to Balloki headworks where industrial, agricultural and municipal waste waters are discharged into it without any treatment.[2,3] The main polluting parameters in the river water are physio-chemicals (BOD, COD, TSS, TDS, metal ions, Anions, pH, colour etc.) and biological (E-coli, bacteriological etc.).[4]

2.1 Pollution loadings in the Ravi

The EPD Punjab has mentioned 32 quality parameters for the water quality. The industrial and sewage drains are discharging waste water into the river without any treatment result the increasing value of BOD and COD in the river water.

A JICA study (2000) revealed that COD level in the River Ravi has

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[1] ibid

[2] Ayesha, A. 2009.Water quality assessment of River Ravi around Lahore city. Pakistan Engineering Congress, 71st Annual Session Proceedings Paper No. 704: 636-648.

[3] Rauf, A., Javed, M., Ubaidullah, M. and Abdullah, S. 2009. Assessment of Heavy Metals in Sediments of the River Ravi, Pakistan. International Journal of Agriculture & Biology ISSN Print: 1560–8530; ISSN Online: 1814–9596: 197-200.

[4] Ejaz, N., Hashimi, H. N. and Ghumman R.A. 2011. Water Quality Assessment of Effluent Receiving Streams in Pakistan: A Case Study of Ravi River. Mehran Univ. Research Journal of Engg & Tech, Volume 230, NO. 3:383-396.

been fluctuated because of the entrance of untreated waste water from the municipal and industrial effluents. The COD level varied from tributaries originated from Eastern side (487 mg/l) to tributaries from Western side (1580 mg/l). In year 2000, the COD level in overall River Ravi was 91 mg/l.[1] Different studies showed that the large amount of untreated effluents discharged into the river Ravi consume more oxygen and reduces the dissolved oxygen level in the natural water due to which aquatic life in the river has vanished.[2] A study showed that the dumping of solid waste at the Shahdara bridge is also a major cause of DO reduction in the water at Shahdara bridge.[3]

A study was carried out during 2009-10 for the assessment of water quality in river Ravi at four sites viz; Ravi Syphon, Shahdarah Bridge, Mohlanwal village and confluence point of Hudiara and Sattukatla drains. The main findings of the study were that the physical parameters like pH, TDS, Cl, F, NO_3, Cu and Zn levels were found within the permissible limits of WHO, Pak-EPA and US-EPA for drinking water quality while E. coli, Turbidity, Pb and Ni (except at Ravi Syphon) were found in all water samples and were in exceeded level than the permissible limits for drinking water quality. The pollution levels are increasing along the direction of flow of River Ravi relative to Ravi Syphon site and were the maximum at the confluence point of Hudiara and Sattukatla drain.[4]

A World Bank study[5] stated that in the River Ravi, the severe impact caused by human activity was between Syphon to head Balloki. The river received 47% of the total municipal and industrial pollution load discharged into all the rivers of Pakistan. The BOD in the river after receiving Lahore municipal discharges was estimated to be 77 mg/l on the annual flow. At Balloki upstream the BOD values were low (2.3 - 3.9 mg/l), DO ranged from 6.2 to 8.2 mg/l, TDS were between 98 and 225 mg/l and sodium absorption ratio (SAR) varied from 0.1 to 0.55.

Another study showed that the ranges of the BOD (90—228 mg/l)

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[1] JICA. 2000. Investigation of Air and Water Quality (Lahore, Rawalpindi, Islamabad): Japanese International Corporation Agency (JICA), Govt. of Pakistan.

[2] Arif, U. 2005. Surface Water Quality modeling of River Ravi (Ravi syphon to Balloki). An M.Sc Thesis, University of Punjab, Lhr: 1—151.

[3] ibid

[4] ibid

[5] Khan, A.U.2010. Evaluation of Industrial environmental management, Pakistan. Final Report. The World Bank: 2.1—2.27.

and COD (64—816 mg/l) from five different sites at the River Ravi.[1] The high BOD and COD values were observed at the Mehmood Booti site and the minimum values were at the Old Ravi Bridge site. Similarly the values of TDS (200-1290 mg/l) and TSS (10—430 mg/l) were observed and the high TDS and TSS values were obtained at the Hadiara drain site and the Mehmood Booti site respectively and minimum values obtained at the Old Ravi Bridge site.[2] A study recommended that the domestic waste water should be disposed off after some waste water treatment system. All the industrial units should install some specific treatments before discharging their effluents. Environmental legislation and enforcement of NEQS are most urgent to improve the stream water quality in Pakistan.[3]

2.2 Metal Contamination in River Ravi

Most of the industrial units are discharging waste water into the drains without any treatment. These drains carry the contaminants and throw them into the river directly or indirectly. These drains' waste water is also used for irrigation purposes, so these contaminants become a part of our food chains, vegetables and fruits. The Dilemma of the system is that there is no check and balance for prohibiting the farmers not to use this hazardous waste water for the agriculture purposes.

Figure-3: Wastewater of drain used for irrigation purposes

Figure-4: Shalimar Escape Channel discharging wastewater without treatment into River Ravi

[1] Iqbal, M. et al. 2011. Bird ecology from the River Ravi of Lahore: Habitat degradation. The journal of plant and animal science, 21(4):817—821.

[2] ibid

[3] ibid

A WWF-Pakistan study (2007) revealed that more than 2 million people in six cities of Punjab were drinking unsafe water, some with a high arsenic concentration.[1] In a study, Arsenic (As) toxicity in water, bed sediments and planktons were found at three major sites of the river Ravi i.e Shahdara Bridge, Balloki Headworks and Sidhnai Barrage. Among these sites the Shahdara Bridge was found having higher concentration of Arsenic. The planktonic biota collected during 14 months of the study period (May, 2009 to June, 2010) showed significant variations with Arsenic concentrations in the river Ravi.[2]

3. Effect of Industrial drains on River Ravi

According to Indus Water Treaty, 1961 Article IV paragraph-4, it was mentioned that Pakistan would maintain in good order its portions of the drainages mentioned below with capacities not less than capacities as on the effective date

i. Hudiara drain ii. Kasur Nalla

iii. Salim shah drain iv. Fazlia drain

If India found it necessary to deepen or widen any of the above drains and if Pakistan would be agreed to do so as a work of public interest, then India would have to pay for that.[3] A study showed that some drains were deteriorating river water and bed sediments by adding effluents from steel industries, pulp and paper, pharmaceuticals etc. and municipal waste water. Those drains were Mehmood Booti, Shad Bagh, Taj Company, Bakkar Mendi, Farrukhabad, Munshi Hospital and Hudiara nulla. The results of this study showed that the metal concentrations in the sediments decreased in the order: Cu > Cr > Cd > Co. These contaminated sediments, accumulated over the years in the river bed sediments could act as secondary source of pollution to the overlying water column in the river.[4]

A study was carried out for the water quality monitoring of Hudiara drain by WWF-Pakistan and Env. Pollution Unit in 2001. It was observed that DO was below 1 mg/l at all sampling points. Also BOD and COD were

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[1] WWF. 2007. Pakistan's water at risk, A special report. Water and health related issues in Pakistan and key recommendations: 1—25.

[2] Jabeen, G.and Javed, M. 2011. Evaluation of arsenic toxicity to biota in river Ravi (Pakistan) aquatic ecosystem. Int. Journal of Agri. and Biol., 13: 929–934.

[3] Govt. of India and Govt. of Pakistan. 1960. Indus Water Treaty:1—22.

[4] ibid

in the range of 104—115 mg/l and 255—276 mg/l which were higher than the NEQS limits. The physical parameters like TDS, Cd, Cu and Mn were above the acceptable limits of irrigation water. E. Coli in all water samples was greater than 180 MPN/100 ml. The annual discharge of about 180 cusec was discharged into the river ravi which was being polluted by high load of BOD and COD. So Hudiara drain is one of the major causes of poor water quality and stress on aquatic life in River Ravi.[1] Another study revealed that mixing of waste water of Hudiara drain and River Ravi resulted a decrease in DO level from 4.5 mg/l to 1.8 mg/l and does not meet the dilution ratio.[2] The DO level was lower at Farrukhabad nullah, Munshi Hospital nulla, Baker Mandi Nullah and Hudiara Nallah as compared to the other sampling stations. [3] A study on the Farrukhabad drain showed that the presence of heavy metals in the water is fully dependent on the Hydrogen ion concentration (pH) in the water. The maximum Zn content were found in Farrukhabad drain at minimum pH (7.47). Zinc conc. varied from 0.4±0.18 mg/l at Q.B. link canal to 3.71±0.88mg/l at Farrukhabad drain. Similarly the iron contents were found to 10.80 ± 4.22 mg/l at Farrukhabad drain. The data of the metal contents showed that the temperature lowers down the metal contamination in the river.[4] Another study was carried out to find the metal toxicity on the river ravi stretch from Shahdara to Balloki headworks. Different sampling points were selected for the analysis and the results revealed that Zn concentration at Farrukhabad nullah and Deg nullah were 3.92 ± 2.04 mg/l and 0.50 ± 0.14 mg/l respectively. Among the river sampling sites, the mean zinc concentration in water at Sharqpur (R3) 'was the highest (0.88 ± 0.45 mg/l) while it was the lowest at Shahdra bridge. Similarly the Iron contents were highest at Farrukhabad nallah (11.89 ± 6.04 mg/l) and was the lowest (3.24 ± 1.01 mg/l) at Hudiara. Similarly the Mn, Pb and Nickel were also in highest amount at

[1] WWF-Pak and EPU. 2001. Water quality monitoring of Hudiara drain. A project funded by UNDP under GEF Small Grants Programme. WWF-Pakistan: 1—79.

[2] Arif, U. 2005. Surface Water Quality modeling of River Ravi (Ravi syphon to Balloki). An M.Sc Thesis, University of Punjab, Lhr: 1—151.

[3] Javed, M. and Mahmood, G. 2000. Studies on the metal toxicity of plankton in the River Ravi. Pak. Journal of Biological Science 3 (12):2165—2168.

[4] Javed, M. and Mahmood, G. 2001. Metal toxicity of water in a stretch of River Ravi from Shahdara to Balloki headwork. Pakistan Journal of Agricultural Science. VOl.38(1-2): 37—42.

Farrukabad drain than all sampling points. This study concluded that water at Farrukhabad, Munshi Hospital, Bakar Mandi nullahs and Degh fall was highly polluted with metals and were higher than NEQS.

4. Effect of river pollution on the Ecology

4.1 Effect on the Human health

The industrialization has converted the River Ravi into sewers and the pollution of Ravi water had been an issue at the upstream of Balloki while at the downstream, the contaminants discharged from industries are diluted because of water of QB link canal. Also in monsoon the excess water is present in river which dilutes the industrial and municipal effluents. Many studies highly recommended that there must be some treatment plant for the Lahore city.[1] There is dire need of awareness among the people to realize their responsibilities for cleaning the canal and river water.[2] Another study revealed that the industrial and municipal effluents are used for the irrigation purpose which is dangerous to the public health.[3] The untreated water used for irrigation is a continuous threat to the food chain. Heavy metals like Fe, Cu, Zn, Ni and other trace elements excess could lead to a number of disorders in the human beings. A study recommended that the effluents should be discharged before some treatments. Also from Marala Ravi Link Canal some 2000 cusec discharge of water should be shared into the River Ravi to dilute the waste water and also to maintain dissolved oxygen level of 4 to 5mg/l which is required for the aquaculture survival.[4]

The links between water quality and health risks were well established in a study. Inadequate quantity and quality of potable water and poor sanitation facilities and practices are associated with a host of illnesses such as diarrhea, typhoid, intestinal worms and hepatitis. The total health costs were estimated at Rs 114 billion, or approximately 1.81 percent of GDP. The high proportions of costs due to premature child deaths, followed by the mortality impacts of typhoid in the older population were striking.[5] A study was conducted in Jamber Khurd to assess the

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[1] Naseer, N.2003. Analyzing the effect of industrial waste on River Ravi. Asian network for Scientific information. Pakistan Journal of Applied Sciences 3(8-9): 587—603.

[2] ibid

[3] Hasan, S.A. and Mustafa, S. 2007. Environmental profile of Lahore canal water. An M.Sc thesis, College of Earth and Env. Sciences, Univ. of Punjab, Lhr:1—52.

[4] ibid

[5] ibid

effect of untreated waste water using as irrigation water. The results showed that in studied area, different kinds of diseases affected 76.07% of the population and only 23.93% were not affected. Most of the persons being investigated were affected by nail problem, skin problem and fever. This study concluded that the percentage of the mentioned diseases was higher in Jamber Khurd area where underground water is polluted due to polluted irrigation water as compared to other sites. This poor quality water had caused health hazard and death of human being, aquatic life and also disturbed the production of different crops.[1]

4.2 Effect on the ecology of aquatic life

The metals are transferred into the fish and through food chain these could ultimately affect the health of people consuming these fish. These heavy metals are cause of untreated effluents discharged into the river through drains.[2]

A study was carried out for the detection of Lead and Nickel toxicity in the body organs of fish in the stretch of River Ravi from Balloki head works to Sidhnai Barrage. The nickel concentration was found the maximum at the Balloki head works (1.30 ±0.32 mg/l) while it was minimum at Syed Wala bridge (0.96±0.21 mg/l). The Kamalia-Chichawatni bridge showed the maximum Lead concentration of 1.66±0.77 mg/l while it was minimum of 0.62±0.27 mg/l at Sidhnai Barrage. The maximum lead concentration was found in fish gills, liver, kidney and muscles. In the fish species of Calta Calta metal accumulation was higher than other two species i.e. lead and nickel concentrations were 12.29 µg/g and 4.67 µg/g respectively.[3]

Another study showed that the fish samples collected from Balloki were having higher concentration of iron and nickel in their bodies than samples collected from Sidhnai Barrage. Lead accumulation in both gills and liver were higher than that in fish muscle kidney. From the above three species of fish, Calta calta had significantly higher tendency for the accumulation of metals in the body. A fish species Cirhinna mrigala showed lower tendency of accumulating the lead than Calta calta and

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[1] Ashraf, M.A. et al. 2007. Effects of Polluted Water Irrigation on Environment and Health of People in Jamber, District Kasur, Pakistan. International Journal of Basic & Applied Sciences IJBAS-IJENS Vol: 10 No: 03: 37—57.

[2] Mahmood, G. 2003. Lead and Nickel concentration in fish and water of River Ravi. Pakistan Journal of Biological Science 6(12): 1027-1029.

[3] ibid

Labeo rohita.[1] A study of 2009-10 showed that the fish were significantly more contaminated with Arsenic at Shahdera Bridge (3.87 µg/g). Similarly the contamination levels found at Balloki headwork and Sidhnai Barrage were 2.79 and 2.47 µg/g respectively in the fish samples. All the six fish species accumulated significantly higher Arsenic concentration in their liver, followed by that in kidney with the mean Arsenic concentration of 3.82 and 3.72 µg/g respectively.[2]

In another study, the toxicities of heavy metals viz. aluminium (Al), arsenic (As), barium (Ba), chromium (Cr), nickel (Ni) and zinc (Zn) in fish were found at three main public fishing sites of the River Ravi. The concentrations of heavy metals in the body organs (gills, liver, kidney, intestine, reproductive organs, skin, muscle, fins, scales, bones, fats) of fish species were determined. The results revealed that the toxicity of metals fluctuated significantly in fish at all the three sampling stations with season. The fish samples collected from all the three sampling stations had significantly higher Aluminum and Zinc concentration. Fish liver and kidney showed significantly higher abilities for the accumulation of all metals while accumulations were lowest in fish muscle and fats. The mean concentrations of metals in the organs of both herbi and carnivorous fish species were in the order of Al > Zn > Cr > Ni > As > Ba. In both herbi– and carnivore fish, the liver showed the mean maximum Aluminum concentrations of 152.66±19.60 and 169.83±11.30 µgg-1 respectively, followed by that in kidney and gills.[3]

5. River Ravi Commission (RRC); An initiative for the solution of River Ravi

A Writ petition was submitted in the Green Bench of Lahore High Court on the issues of discharge of untreated municipal and industrial wastewater into the River Ravi in 2012 by Public Interest Litigation Association of Pakistan (PILAP), PELA and LCS. In the writ, it was stated that major disposal of wastewater in the River Ravi occurs in the 84 kilometers reach of the river between the Ravi Syphon and the Balloki Headworks. As a response of writ petition, Lahore High Court made a Commission for reviving the ecology of River Ravi. The Commission is

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[1] Javed, M. 2005. Heavy metal contamination of freshwater fish and bed sediments in the River Ravi Stretch and related tributaries. Asian network for Scientific information. Pakistan journal of Biological Sciences 8(10):1337—1341.

[2] ibid

[3] ibid

working under the chairmanship of Dr. Kauser A. Malik and has members from the provincial Government Departments (EPD, WASA, Irrigation, Commissioner office, Advocate General Punjab etc.), representatives from non-government organizations and technical experts for the solution of controlling the pollution in River Ravi with some practical and feasible solutions using indigenous technologies.

5.1 Achievements of the Commission

- RRC arranged different meetings and invited experts to suggest some indigenous treatment technology for the treatment of the waste water of Lahore in order to save the ecology of the river Ravi. After the studies the Commission concluded that the bio-remediation treatment with concept of constructed wetlands is the most suitable and cheaper technology for the wastewater of the Lahore.
- Mechanism of Cooperation among different departments, stakeholders was developed which was appreciable i.e WASA, EPD, Commissioner Office, different private agencies cooperated and assisted the commission in different aspects.
- The Commission gathered the data and observed that more than 1380 industrial units have been issued notices by EPD for not complying the NEQS standards in discharging their effluents. Also there are 105 industrial units which are discharging heavy metals more than NEQS. There are 29 industries which are complying wastewater treatment plants in Lahore.
- The data was collected from different sources and it was investigated that the drains in Lahore are discharging directly and indirectly wastewater into the river Ravi without any treatment. The more toxic drains are Hudiara drain, Farrukhabad nullah, Bakar mandi nullah, Munshi Hospital.
- The Lahore High court in its hearing on 1st March 2013 ordered the Commission to proceed further for the construction of bioremediation treatment system with concept of constructed wetlands.

5.2 The Bio-remediation treatment for River Ravi

In the past, a number of studies on the wastewater treatment plants for Lahore had been conducted by national (NESPAK) and international consultants but because of high capital cost couldn't come into the practical phase. Recently a few proposals of the treatment system are in pipeline. So, the RRC explored the existing wastewater treatment systems in Pakistan and recommended the bioremediation treatment technology (with concept of constructed wetlands) as the most suitable and economical technology for the wastewater treatment of Lahore.

Bioremediation is the use of micro-organism metabolism, plants and enzymes to remove pollutants from the water. Constructed wetlands (CWs) are engineered systems which are designed and constructed to utilize the natural processes and microbial consortia for treating wastewater.

Constructed Wetlands are classified according to macrophytes like free-floating, rooted emergent and submerged plants. On the basis of hydrology, Constructed wetlands (CWs) can be classified as Free Water surface Flow (FWS) and Sub-Surface Water flow (SSWF). Further on the basis of water movement the wetlands may have horizontal flow and vertical flow. Constructed Wetlands are effective in treating BOD, TSS, N and P. These wetlands are also helpful for reducing metals, organic pollutants and pathogens. The principal pollutant removal mechanisms in constructed wetlands include biological processes such as microbial metabolic activity and plant uptake as well as physico-chemical processes such as sedimentation, adsorption and precipitation at the water-sediment, root-sediment and plant-water interfaces.[1]

The Commission submitted its findings in the Court and suggested to construct a wetland initially as a demonstration project of 10 cusec of waste water. A piece of land at Babu Sabu covering an area of about 50 acres has been proposed for the development of constructed wetlands and this land can be acquired from WASA. Based on the performance of this unit further decision will be made. The High Court directed the Commission to proceed further for the construction of wetlands.

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[1] Wetlands International, Malaysia. The use of constructed wetlands for wastewater treatment.

	
Fig. 5 Drain at Babu Sabu	**Fig. 6 Land at Babu Sabu**
	
Fig.7 Constructed wetlands working in NARC Islamabad	**Fig.8: Phyto-remediation in the ponds, China**

Cost effectiveness of the system

Different proposals of wastewater treatment systems were in consideration in the past. WASA has acquired two sites in Lahore for wastewater treatment i.e. Southern side (Babu Sabu) and Northern side (Near Mehmood Booti). WASA has conducted different studies on wastewater treatment system and recommended the Waste Stabilization Ponds as treatment technology for large scale treatment of Lahore wastewater. In comparison with it, the Constructed wetlands require less land and low capital cost i.e. Rupees 50-70 Milion for 10 cusec wastewater treatment system with Rupees 5-6 Million running cost per year.

Note: If the bio-remediation treatment plant will be working properly, it will treat about 1.28 M. m^3 of wastewater annually. Though this amount of water is very less than the total production of wastewater but it is a step forward practically for restoring the ecology of the river Ravi.

6. Recommendations

Pursuant to the above discussion it is recommended that:

- There should be some treatment system for the wastewater coming from the drains into the river. The fish species should be provided some treated water for eco-balance. There should be some wastewater treatment which should be simple, indigenous and cost effective as suggested by the River Ravi Commission i.e. Construction of bio-remediation treatment plant with concept of constructed wetlands for the treatment of wastewater before discharging into the River. The organic waste (after plant harvesting) from the bio-remediation treatment can be used as a resource for biogas production.
- The industries should discharge wastewater after some treatment like primary treatment, secondary treatment. In the housing societies some septic tanks must be constructed because the septic tanks reduce major portion of the organic loading easily.
- There is a lot of pollution found in the drains which are carrying hazardous materials, heavy metals and other toxicants. Some phyto-remediation techniques should be applied in these flowing drains for the metal adsorption and pollution reduction.
- There should be some ground water abstraction policy in the Punjab Province on emergency basis. As the Lahore's water drawdown curve is going down because of over abstraction so on urgent basis some strategy should be developed for allotting some limited number of connections for groundwater tube-wells for domestic and industrial purposes.
- There should be restriction for the usage of industrial effluents for the irrigation purposes.

Global Food Loss and Waste within Food Supply Chain with Special Reference to Pakistan (Causes & Preventions).

Tayyaba Rizvi[1], Riffat Saqlain[2], Qamber Raza[3]

Abstract

This study review the losses and waste of food within food supply chain at global level with special reference to Pakistan. An international literature review shows food wastage at distribution and consumption stage in high income countries and food loss in low income countries majorly at post harvest stage as it is evident in case of Pakistan. A significant gap exists in the literature on the underlying study for Pakistan related to post harvest losses for both perishable and non-perishable food stuff. Therefore, this study provides a review on post harvest losses on both these types of food stuff in Pakistan. Causes and preventions of food loss and waste are also drawn on the basis of the results of the reviewed studies. The analysis of this review shows post harvest losses in Pakistan are majorly at storage stage in case of non-perishable food stuff. However, time lag in transportation and improper handling of fruits and vegetables are the major cause of loss for perishable food stuff in Pakistan.

Key words: Food loss and waste; post-harvest loss; perishable; non-perishable; Pakistan.

INTRODUCTION

Food loss and waste is a serious global issue for the growing world's population. About 900 million people are hungry worldwide and one billion people are overfed. At global level there is a need to increase food production by 60% by 2050 FAO(2010). This challenging situation depicts the widening gap between the world food demand and its availability. However, out of produced food 2609 Kcal/cap/day, 614

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Kcal/cap/day food supply is lost and wasted at global level which is almost 2.4% (Kummu *et al,* 2012). Around one third of food produced for human consumption is lost or wasted globally (Gustavsson *et al,* 2011). Food loss and waste usually takes place within the food supply chain. Only difference is: food wastage is at greater extent at distribution and consumption stage in high income countries while food loss in low income countries is at early stages of supply chain as evident from other studies i.e., Gustavsson *et al,* (2011), Parfitt *et al*, (2010). However, in developing countries like Pakistan food loss is majorly at post harvest stage (Rolle *et al*, 2006). Pakistan is heavily dependent on its agriculture sector, contributing 25% of gross domestic product even after facing considerable changes over the years. This study fills the gap in existing literature by reviewing both perishable and non-perishable post harvest losses of food in Pakistan. However, literature shows individual studies have been carried out on either of post harvest losses in Pakistan and are very few.

1.1. Definition and Materials

Food loss refers to the decrease in food quantity or quality, which makes it not fit for human consumption (Grolleand, 2002). Food loss occurs at different stages of food supply chain such as production, post-harvest and processing stage (Parfitt *et al*, 2010). The term food waste expresses the loss of food during distribution and consumption as also mentioned by other studies (Kummu *et al* 2012; Gustavsson *et al* 2011; Parfitt *et al* 2010). It is often quoted that as much as half of all food grown is lost and wasted before and after it reaches the consumer (Lundqvist *et al* 2008). Therefore, food loss or waste takes place at five stages of food supply chain (FSC) for which brief explanation of the definition[1] is as:

a. Agricultural Production

Loss of food in agricultural production is due to mechanical damage and/or spillage during harvesting operation and crop sorting. Food loss can take place due to poor harvesting techniques, unsuitable soil for crop yield resulting loss in food quality.

b. Post- harvest Loss

Post- harvest refers to position in which edible commodity is separated from the plant that produced it by a deliberate human act with the intention of starting it on its way to table (FAO, 1981; Bourne, 1977;

[1] For more details see: Gustavsson *et al*(2011); Partiff *et al* (2010); Stuart (2009), Kummu *et al* (2012).

Harris & Lindblad, 1978 & National Academy of Sciences of US, 1978). The post-harvest period ends when the food comes into the possession of the final consumer. Post-harvest food loss is due to the storage and transportation between farm and distribution, spillage and degradation during handling. Pests attack and natural drying out of food at the time of storage can also cause food loss. The method of measuring the quantity of food in the post-harvest stage should be on weight basis. Post-harvest loss is often used when describing agricultural systems and the onward supply of produce to market (Parfitt *et al* 2010).

c. Processing Loss

Processing loss refers to the losses during industrial and domestic processing. Crops are sorted out not only at primary processing stage i.e., cleaning, soaking, drying, packaging, grinding but also at secondary stage of processing. Product evaluation through quality assessment and standardization of quality in order to meet the international market competition with respect to price and worth can lead to food loss during processing.

d. Distribution Waste

It includes loss and waste in the market system that includes wholesale markets, supermarkets, retail market and wet-markets. Damage caused to a commodity during transportation or poor handling in wet-markets cause food waste.

e. Consumption Waste

Food wasted through consumption includes loss or waste during consumption at the household level. Poor storage management and facility at home causes discarding of food before it gets served. Food waste at household level can also be wasted/consumed because of "best before" and expiry dates mentioned on the packaging.

2. Global Trends

2.1 Food Production and Supply.

At global level one-third of food produced for human consumption is lost or wasted which amounts to 1.3 billion tons per year (Gustavsson *et al*, 2011). This shows the increasing gap between the world's increased consumption of food and the world food production. Over the last five decades between 1961- 63 and 2007-09 production has increased by a massive 170 percent. Still food is not available for all. Beyond per capita consumption, little less than 1 billion people in 2010 were estimated[1] to be insecure. Per capita food availability for the world as a whole has risen from about 2220 Kcal/person/day in the early 1960's to 2790 Kcal/person/day in 2006-08. Developing countries recorded an increase from 1850 Kcal/person/day to over 2640 Kcal/person/day (FAO Statistical Year Book, 2012b). Food crop account for 83% of total food supply (2761Kcal/person/day); averaged over years 2005-2007. However, animal products account for 17% (FAO Statistical Year Book, 2012b). On average total production of food crop provides 3938 Kcal/cap/day in year 2010. Globally around half of the total supply of food is consumed by humans' over one quarter is directed to animal feed (Kummu *et al,* 2012). In recent years food production plus imports minus exports plus change in stock (decrease or increase) is used to calculate the supply of domestic utilization of food (FAO, 2001). Increase in yield and higher cropping intensity over the past fifty years caused growth in the world crop production.

2.2 Food Loss and Waste

Food loss represents a significant cost to the world economy and greatly impact the feeding ability of the world (FAO, 2012). Food loss and waste is an issue in all major economies of the world as it takes place at each stage of food supply chain. The world can be divided into two parts (a) low-income countries (b) middle – high income countries in order to examine the food loss and waste at each different stage of food supply chain. Only difference is: In middle – high income countries food is wasted at a greater extent at the distribution and consumption stage.

Food is discarded even if it is still capable for human consumption. However, in low – income countries mostly food is lost during harvesting, post – harvesting and processing stage much less food is wasted at consumer level. More than 40% of food loss takes place at post –harvest and processing level in developing countries. In industrialized countries significant food loss occurs in early food supply chain besides food wastage at retail and consumer stage. At consumer level food waste is 222 million tons that is almost as high as the total net food production of 23 million ton in Sub-Saharan Africa (Gustavsson *et al*, 2011). In Sub-Saharan Africa alone Post- harvest grain loss are around US $ 4 billion which can meet the minimum annual food requirement of 48 million people (FAOSTAT, 2013). Although the agriculture sector of Sub-Saharan Africa

[1] For more details see: FAO Year Book (2012a).

contribution is 20% to 40% of its gross domestic product (GDP) (Godfray *et al,* 2010).

At global level 24 percent of food is lost and wasted as food supply production is 2609 Kcal/cap/day whereas the food supply loss and waste is 614 Kcal/cap/day (FAO, 2012b). (Gustavsson *et al*, 2011) estimated per capita waste produced by consumers is between 95-115 kg a year in Europe and North America. However, in Sub-Saharan Africa and South East Asia, consumer food waste accounts only 6-11 kg a year. Morisaki, (2011) studied patterns of food loss and waste in Japan. The result of the study shows that Japan's industry and household both discard nearly 17 million metric tons of edible food, nearly 30 % of annual production. (Kumar, 2011) used loss- adjusted national food availability data for 134 food commodities in United States. The result of the study indicates that available food wastage in United States exceeds 55 million metric tons per year, nearly 29% of annual production. Parfitt *et al,* (2010) losses are much higher at the immediate post- harvest stage in developing countries. However, across industrialized and developing countries food loss is higher for perishable foods. In case of affluent economies, post-consumer food waste is greatest of overall losses. On examining food waste from retail and wholesale sector for Denmark, Sweden, Norway and Finland, Stenmarck *et al,* (2011) indicates that annual retail waste lies between 40,000 to 83,500 metric tons in each of these countries. On comparing, the retail and wholesale waste of larger economies of Japan, UK and US with that of these countries showed higher magnitude of food waste in the same stage of food supply chain.

The Asia- Pacific region is approximately 30% of the world's land area. Of which China, India, Pakistan and Indonesia are among most populous countries. In China, food waste has increased rapidly and is about 70 % of house hold and commercial waste (Xin *et al,* 2012). In India post- harvest loss of fruits and vegetables are nearly 30 % which is due to the lack of availability of cold storage. Grain loss is more than 30 percent due to the grain supplied through the public distribution system (Mukherji & Pattanayak, 2011).

3. Food Loss and Waste Condition of Pakistan

3.1 Introduction

Pakistan is an agrarian economy based on geographical area of about 79.61 million hectors of which 22.04 million hectors is under cultivation almost about 28%. Being the dominant sector of the economy, agriculture contributes 25% of gross domestic product even after undergoing considerable changes over the years. Pakistan's population in mid 2004 was estimated 148.72 million. However, it has increased considerably at an average rate of 2.6% per annum of which 44% of country's working force is employed in agriculture sector. In recent years agricultural income has reduced causing increase in rural poverty to 38.9% by 2002 (World Bank, 2011). However, it was 22% to 26 % in FY 1991 (Economic Survey, 2000-01). Almost 38% of small land owing farmers are also poor (World Bank, 2008). Increasing population and poverty indicates a widening gap between food demand and food availability.

3.2 Food Volume Produced

Food crops are mainly divided into four major groups[1] such as (i) Cereals (ii) roots and tubers (iii) oil crops and pulses (iv) fruits and vegetables. Pakistan's major agricultural crops are wheat, rice, cotton, sugarcane that accounts for 41% of value added in overall agriculture. On average these four crops contributes 36.5% to the value added in agriculture. Minor crops such as pulses, potatoes, vegetable and fruits accounts 10% of value added (World Bank, 2011).

Table 2

Food Crop Produced In Pakistan

	Area		Yield		Production			
Commodities	000 ha (2010)	% p.a growth	Tons per ha 2010	% p.a growth 2000-10	000 tons 2009	000 tons 2010	% p.a growth 1990-99	% p.a growth 2000-10
Wheat	9132	0.8	2.6	0.2	24033	23311	2.5	1.0
Rice	2365	-0.0	3.1	0.1	10324	7235	5.2	0.0
Oil crop	3307	-0.8	0.3	1.3	1021	891	3.0	0.6
Roots & tubers	165	1.9	21.6	2.5	3383	3570	8.0	4.5

Source: FAO Statistical Year Book (2012b).

Table shows declining trend for the food crop produced in Pakistan during year 2000 to 2010. However, the cultivable area for wheat is highest of all but its production declines from 24033 to 23311 thousand tons during 2009 and 2010 respectively. Similarly, in the same years rice production declined from 10324 thousand tons to 7235 thousand tons showing reduction of 3089 thousand tons of rice. Roots and tubers growth

[1] For further details see: Kummu *et al* (2012), Gustavsson *et al*, (2011), FAO (2012).

reduced to half of what it is produced during 1990 to 1999.

3.3 Food Loss within Food Supply Chain

Pakistan like other developing countries faces food losses at different stages of food supply chain such as harvest, post- harvest and processing stage much less is lost at consumer stage but major loss is at post-harvest stage (Parfitt *et al*, 2010). However, post harvest losses can be divided into two types of food stuffs (i) Perishable (ii) Non- Perishable food stuff. This section reviews post harvest losses for both types of food stuffs, very few data sets were available for both these types related to the losses existing in Pakistan.

3.3.1 Post-Harvest Loss for Non Perishable Food Stuff

Non perishable food stuff includes cereals such as wheat, rice, barley, maize.

3.3.1.1 Wheat Production and Losses

Wheat is the most important food crop in Pakistan based on 9132 thousand hectare for year 2010. Pakistan's annual per capita wheat consumption is 150 Kg which is higher than India, China, Vietnam and Sri-Lanka. Pakistan's wheat production declined from 24033 thousand tons to 23311 thousand tons during year 2009 to 2010 respectively. However, for the last two decades (i.e., 1990-99 and 2000-2010) the percentage growth of wheat declined from 2.5% to 0.1% (FAO Statistical Year Book, 2012). Wheat loss in Pakistan is at storage stage caused by insects and to a lesser extent by rodents and fungi if wheat is stored for three months or longer (Baloch, 1999). Storage loss of wheat in Pakistan during 1984-85 was 2.1%, 0.9 % due to pre-storage and 0.4% is due to storing wheat in moulds for an average storage period of 5.4 months (Baloch *et al*, 1994). (Ibupoto *et al,* 1991) evaluated field grain losses in wheat variety Sarsabz harvested, threshed and winnowed by following conventional methods at Malir farm in Sindh. Using data for 30 samples showed that for traditional methods the average grain losses during pre-harvest, harvest and post harvest stages were 10.9, 28 and 122.9 Kg/ha or 0.28%, 0.77% and 3.28%. the post harvest grain losses were the highest. Among post harvest grain losses bundling losses were maximum 1.41% followed by threshing 1.02%, winnowing 0.66% and transportation 0.12%.

(Chaudhary, 1980) carried out a comprehensive study on post harvest losses of food grain in all four provinces of Pakistan occurring at harvesting, threshing, cleaning, drying, milling, storage, processing, cooking and consumption stages. The result of the study indicates aggregate losses during various post harvest operations in Pakistan are

17.1% in paddy, 15.3% in wheat and 12.6% in maize. Women in Pakistan's farm families are traditionally responsible for the storage of food especially cereals grains. About 54% of wheat is stored at farm level for which small quantity of grains containers made of woven plant material plastered with mud and wooden boxes are commonly used. Larger amounts of food grain losses are mainly because of farmer's unfamiliarity with appropriate on farm storage technology and poorly constructed and maintained stores (Khan, 1983). However, such techniques are still used by small farmers to store wheat in the current time period due to which wheat loss takes place.

3.3.1.2 Rice Production and Losses

Pakistan's average rice yield is comparatively low than China, USA, North Korea, South Korea, India, Bangladesh, Vietnam, Philippines, Brazil, Egypt and Iran (Khan & Khan, 2010) covering the crop area equivalent to 2365 thousand hectares Rice yield of Pakistan. Rice yield of Pakistan per hectares is 3.1 for the year 2010. However, production declined from 10324 to 7235 thousand tons for the year 2009 and 2010 respectively (FAO, 2012).

Pakistan produces different varieties of rice of which Basmati and IRRI (International Rice Research Institute) are famous. On average of year 2006-07 to 2008-09, Pakistan's total rice production was 5983.93 thousand tons in which 55.5%, 34.28%, 2.12% and 8.10% was contributed by Punjab, Sindh, NWFP and Baluchistan. However, during the same period, Basmati rice production was 2502.47 thousand tons and 2692.67 for IRRI (Khan & Khan, 2010). Post- harvest losses of rice takes place at different stages such as cutting, field drying, bundling, transport, stacking, pre-threshing, threshing (including cleaning), drying, parboiling, storage and milling. In Pakistan post harvest losses are majorly at storage stage for rice. Loss assessment based on field survey of rice shows post harvest loss in Pakistan for paddy drying which is 0.5%. This loss in weight and value increases if the harvested bundle remains several days in the field (Grolleaud, 2002)

Manual rice harvesting and threshing methods in Punjab, Pakistan besides using reconditioned wheat combines for rice harvesting in Punjab, results in post harvest losses of rice. Sizable field loss and internal damage to harvest rice grain along with the affected milling quality is due to poorly trained operators (Khan & Salim, 2005). Heavy grain loss occurs at the time of early or late harvest. Early harvest causes broken Kernels and low milling recovery. Late harvest crop is subject to pest attack, bird pests besides the risk of lodging and grain shattering. Manual harvesting, field drying bundling and stacking in traditional system can result in 2-7% losses, 0.11% to 0.35% losses during field transport, 0.11% to 0.76% during field stacking even greater percentage of loss occurs when stacking is left in the field with increased grain moisture contents (Rehman, 2008).

In summary, post-harvest losses in Pakistan for non-perishable food stuff is majorly at storage stage.

3.3.2 Post- Harvest Loss of Perishable Food Stuff

Post-harvest loss of perishable food occurs almost in every country but the percentage of loss is higher in developing countries like Pakistan where the need for food is greater. For instance, tomato is a fruit used as vegetable in Pakistan, covering 0.03 million hectare of total area of production of tomatoes in Pakistan of which production is more than 0.3 million metric tons. (MINFAL, 2005). (Rehman *et al,* 2007) estimated post –harvest losses in tomato crop produced in Peshawar valley of Khyber Pakhtunkhwa a province of Pakistan. Based on randomly selected 68 tomato growers in the area their result indicates 20% post-harvest loss of tomato of total production. These losses mainly occurred during picking of the crop, handling and transportation to the markets. (Saeed & khan, 2010) carried out a similar study for the district Lahore of Punjab province focusing on the shelf life of tomato based on the systematic survey of the distribution of tomato crop in market of district Lahore. Their result indicates more than 30 % post-harvest losses of tomatoes. The deterioration of the produce are found due to packing material which was 25%, transportation system that was 10% and means of distribution was 5%. The result of the study also indicates that sometimes the whole lot of tomatoes distributed in the markets of the district Lahore is lost. Time lag in transportation, bulky packing in the traditional wooden crates wrapped with papers causes damage to the tomato crop.

Pakistan is existing in the Asia- Pacific region which has strong growth in (FFV) Fresh fruits and Vegetables (Rolle, 2006). Pakistani fruits and vegetables are in world demand. Major fruits produced in Pakistan are Citrus, Mango, Banana, Apple, Guava, Apricot, Peach, plums, grapes, pomegranate, dates which contributed 5712.4 thousand tons in quantity during 2003-04. Pakistan is not only producing and consuming fresh fruits and vegetables domestically but is also exporting fruits and vegetables to different countries (Anjum & Awan, 2006). Due to inadequate management at different stages of food supply chain such as poor quality inputs, poor cultural practices at production level, lack of knowledge related to harvesting, post-harvest handling, packing and packaging, lack of cooling and transportation facilities especially lack of storage facility of fresh fruits and vegetables in warm weather all leads to losses of fresh fruits and vegetables. However, the post harvest loss of fruits produced in Northern Areas of Pakistan ranges from 6.7% to 62.57%[1]. (Khan *et al,* 2008) estimated post- harvest loss in peach production in district Swat. Based on randomly selected eight growers, the result indicates 77% loss at peach picking stage while 23% loss occurs during transportation stage.

In summary, post harvest loss of food for perishable food stuff in Pakistan is mainly caused by time lag in transportation and improper handling of fruits and vegetables due to which damage to the perishable food stuff takes place.

4. Causes and Preventions of Food Loss and Waste

4.1 Causes of Food Loss and Waste

Food loss and waste exists throughout the food supply chain not only at the time of harvesting but till the end of the consumption stage. However, the magnitude and the major causes differ from one country to another. Therefore, this study presents major causes of food loss and waste based on the findings of the reviewed studies.

Developing countries like Pakistan where more than two-third's of Pakistani live in rural areas, relying on food supply chain with limited post harvest infrastructure, technologies, poor storage and lack of transportation facility, feeding majority of urban population faces food loss due to premature harvesting. This premature harvesting by poor farmers is usually to fulfill the increased demand for food by consumers and to earn income for their poor families due to which low quality food is produced that brings low returns to the growers, processors and traders.

Lack of availability of storage facility (i.e., cold storages) to preserve fresh fruits and vegetables in hot and humid weather also cause loss of food in developing countries before it reaches to the consumer.

Improper handling and poor market facilities of post harvested food for both perishable and non perishable food stuff also causes food loss in developing countries.

Lack of investment in new technologies and lack of use of improved seeds cause food loss in developing countries.

In industrialized countries food loss occurs at retail and consumer

[1] For detail see: Anjum and Awan (2006).

level as manufacturers of super markets cannot sell their excess produced commodities elsewhere and it becomes waste.

Excess production as compared to the demand causes loss of food in industrialized countries.

In developed countries food is wasted at the time of cooking, preparing and serving.

Best before date and expiry date on food packing causes food waste in developed economy.

A slight damage to the edible products reduces its quality standard in markets in developed countries.

4.2 Preventions of Food Loss and Waste

Investment in new technologies and the utilization of high yielding seeds besides increasing the harvesting techniques of production can prevent food loss at the post harvest stage (Khan & Salim, 2005).

Technical knowledge and skills in order to increase production can reduce food loss within food supply chain. (Godfray *et al,* 2010).

Super markets are the dominant intermediary between farmers and consumers, coordination between these two can reduce the food wastage in industrialized countries (Reardon *et al,* 2007).

Surplus food produced in industrialized countries can be stored for lean years by opting Investment and engineering skills for suitable storage facilities (Parfitt *et al,* 2010).

Food pricing policy must be designed in such a way that the global commodity prices do not disincentive the food producers in developing countries (K. Anderson, 2009)

Conclusion

Around one third of food produced for human consumption is lost or wastes globally within food supply chain. Therefore, with the growing demand for food along with the population at the global level this study concludes that there is need to take immediate steps to control food loss and waste at each stage of food supply chain. The analysis of this review shows food wastage at distribution and consumption stage in middle-high income countries and post harvest loss at each stage of food supply chain in case of low income countries. Considering both aspects of perishable and non-perishable food stuff, the analysis also shows post harvest food loss in Pakistan. However, post harvest losses in Pakistan are majorly at storage stage for non-perishable food stuff. Time lag in transportation and improper handling of fruits and vegetables reduces the quantity and quality of perishable food items. Irrespective of global regions, there is a need to focus on the reduction of global food loss and waste. High income countries can support low income in reducing food loss by providing technical skills and knowledge at farm level. Pakistan can reduce food loss of both perishable and non-perishable food by improving transportation facility, marketing and storage facilities (i.e., cold storage at whole sale and retail outlets) in order to preserve fresh fruits and vegetables.

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TRANSFORMING FOOD WASTE INTO A VALUABLE RESOURCE THROUGH ANAEROBIC CO-DIGESTION

Muzammil Anjum, Azeem Khalid*, Tariq Mahmood[1]

ABSTRACT

During the last decade food industry has grown tremendously all over the world, which has created several problems including depletion of natural resources, energy crisis and waste generation. Food wastes must be managed in a sustainable way to reduce environmental burdens and minimize risk to human health. Recently, the interest has been renewed to utilize food processing biomass for the production of energy and resource production. Anaerobic digestion is considered as one of the most viable options for converting raw solid organic wastes into useful products. Co-digestion of substrate mixtures is used for improving yields of anaerobic digestion and stabilizes the feed to the bioreactor. Our recent studies have shown that an addition of melon waste at the rate of 300 g kg^{-1}significantly increased the biodegradation rate and biogas production compared to solid organic waste alone.Similarly, co-digestion of catering waste and wheat crop residues significantly enhanced the biogas production compared to single substrate. These findings illustrate that anaerobic co-digestion could be an appealing option to transform raw solid organic materials into useful resources such as biogas and other energy-rich compounds, which may play a critical role in meeting the world's ever-increasing energy requirements in the future.

Key words: Co-digestion, Biogas, Crop Residues, Food Waste, Energy

CONTENTS

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1. INTRODUCTION

One of the most important pillars of increased living standards through socio-economic development is energy (Mirza, 2008). It is also known as the factor of economic growth. The consumption pattern and quality of the energy utilized determine the economic state of any region. These two indicators change in accordance with the economic growth of the country, thus accounting the source and availability of the energy, further the efficiency of the energy being utilized in the economic growth. (Mirza, 2008; Ramachandra, 2004). The most commonly used energy resource is fossil fuel, but have their prominent environmental issues related to the global warming and pollution (Su, 2009). These energy demands are on constant rise due to increased population and growing standards of life.

In the present conditions of population growth and substantial increase in the living standards has also resulted in production of high volumes of municipal solid waste and proving a challenge to management worldwide. Varying technologies are employed for the production of energy utilizing solid waste, few are; anaerobic digestion, incineration and Refuse Derived Fuel etc. Among these anaerobic digestion is of competent interest, with variety of research work going on worldwide. The high energy demand and influential prices have further made the anaerobic digestion process the most attractive ground of research for energy production with dual benefits of waste reduction and energy recovery (Zhu, 2009). The anaerobic digestion process involves conversion of organic matter into biogas along with the benefits of odour reduction and waste minimization (Kafle and Kim, 2013). Contemporary research have proven the use of different type of organic wastes like agricultural waste and municipal solid waste (Lai et al., 2009)for biogas production through anaerobic digestion. Further studies have also shown that of food waste and kitchen waste could also be employed for the production of biogas through Anaerobic Digestion (AD). Similarly, enhancement of methane recovery through anaerobic digestion of kitchen waste has also been reported (Kuo and Chen, 2007; Lai et al., 2009).

The efficiency of anaerobic digestion is dependent on many factors like characteristics of waste and reactor. Other important considerations include temperature, organic load, solid and nutrient content and buffering capacity of the waste. Using food and vegetable waste for anaerobic digestion has few limitations corresponding to its acidification during the digestion process that inhibit the effectiveness of methanogens (Misi and Foster, 2008; Bouallagui et al., 2005;Kafle and Kim, 2013). However it was also found that the efficiency of anaerobic digestion could be increased by utilizing some modifications in the process that facilitates the digestion. One of the promising modifications is co-digestion of organic waste that improves the digestabalility of the waste (Alkaya and Demirer, 2011).

Co-digestion improves the digestion process by improving nutrient and organic load and diluting the toxic compounds, the supplementary effect of the microbial synergism further improves the digestion and biogas production. Hygienic stabilization and increased digestion rate are some other additional advantages of co-digestion (Sosnowskiet al., 2003). This review focus on the co-digestion of food waste with different organic wastes.

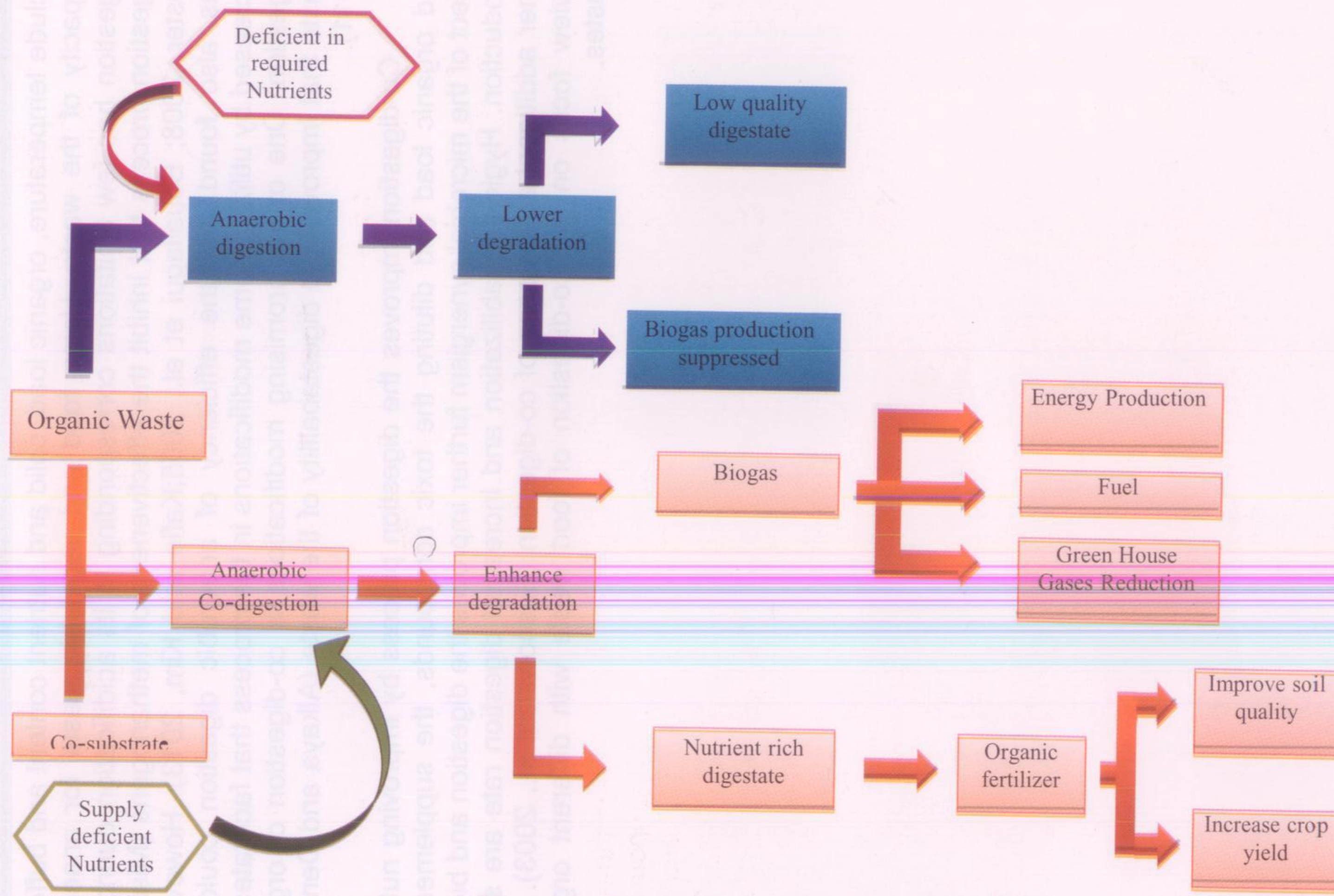

Figure 1: Anaerobic co-digestion flow chat

1. ANAEROBIC CO-DIGESTION

Figure 1 describes the comparison between co-digestion of two substrates and anaerobic digestion of single substrate. Anaerobic co-digestion process involves simultaneous digestion of different types of organic waste in a reactor, that increase the performance efficiency (Hamzawiet al., 1998; Zhang and Banks, 2008; Bouallaguiet al., 2009). The process is also helpful as it reduces the requirement of nutrient (Nitrogen & Phosphorus) addition from external source (Pavanet al., 2005; Neveset al., 2008; Bouallaguiet al., 2009). During the process the concentrated substances are evenly distributed that allows dilution of the substances that could be inhibitory to the process otherwise (Sosnowski, 2003). Beside production of biogas, this process is also an effective option for management of various organic wastes.

Microbial degradation specifically bacteria are dependent on the characteristic of the waste. The important considerations include balancing many micro and macro nutrients, biodegradable organic matter and dry matter, stabilizing C:N ratio, pH and reducing toxic compounds to aid the process of digestion (Alvarez et al., 2010). Like anaerobic digestion process for single waste, the co-digestion process also involves three steps. These can be differentiated in to following three stages (Sosnowski et al., 2008; Gelegenis et al.,2007):

- Stage 1: organic compounds are being converted to soluble compounds by the action of extracellular hydrolytic enzymes produced by certain bacteria
- Stage 2: the soluble component is converted by acid forming bacteria into volatile acids
- Stage 3: the acetogenic bacteria along with the methanogen bacteria convert the volatile fatty acids into methane and carbondioxide

2. SIGNIFICANCE OF ANAEROBIC CO-DIGESTION

Co-digestion is feasible option for management of waste due to its ecological, technological and economic benefits related to conversion of waste in valuable form through anaerobic digestion. The scope of anaerobic co-digestion covers variety of the wastes that include food industry wastes (Alvarez et al., 2010) animal manure (Gungor-Demirci and Demirer, 2004, Umetsuet al., 2006), municipal solid waste (Zupancic et al., 2008), waste water sludge (Romano and Zhang, 2008), fish wastes and algal sludge (Yen and Brune, 2007). These waste can be co-digested with food waste to enhance the digestion performance. Few studies related to the anaerobic co-digestion are represented in Table 1. Alkaya and Demirer (2011) describes the benefits of co-digestion include: balancing suitable ratio between required nutrients, diluting potential toxic compounds (Sosnowski et al., 2003), supplying buffering capacity (Kivaisi et al., 2004), sharing the equipments, establishing required moisture content, and easing the handling of wastes. Anaerobic co-digestion is also applicable in the situations where the anaerobic digestion of single type of waste is not possible due to low organic content at particular site (Sosnowski et al., 2003).

However there are also some detriments related to anaerobic co-digestion. Due to high organic content and readily available carbon source it may provide breeding ground to many infectious vectors that limit the use of treated material, thus it requires careful consideration and handling

Table 1: Biogas potential of various food wastes through anaerobic co-digestion (modified from Khalid et al., 2011).

Substrate / Co-substrate	Reactor Type	Biogas production rate (l/d)	Methane yield (l/kg VS)	References
Dewatered sludge / food waste	Stirrer reactor	10.7	960	Dai et al., 2013
Fruit and vegetable waste /Abettor Waste	Sequencing batch reactors	2.53	611	Bouallagui et al., 2009
Municipal Solid Waste / Fly ash	Anaerobic bioreactors	6.50	222	Lo et al., 2010
Municipal Solid Waste / Fat, oil and grease waste	Batch Reactor	13.6	350	Martin-Gonzalez et al. 2010
Potato waste / Sugar beet waste	Batch reactor	1.63	680	Parawira et al., 2004

Primary sludge / Fruit and vegetable waste	Stir reactor	4.40	600	Gomez et al., 2006
Sewage sludge / Municipal solid waste	Continuous stirred tank reactor	3.00	532	Sosnowski et al., 2003
Slaughter house waste / Municipal solid waste	Semi-continuous reactor	8.60	500	Cuetos et al., 2008

during the establishment of reactor (Luostarinen et al., 2009). The resultant solids of anaerobic co-digestion are not appropriate for land application as it has high odour moisture and volatile fatty acids which is phytotoxic (Walke et al., 2009). Overall anaerobic co-digestion is an important technology to convert waste to energy. Jingura and Matengaifa(2009) suggested few benefits of the process given below:

- Co-digestion improves the nutrient balance, thus could maintain a stabilized performance of the digestion correspondingly better fertilizer quality could be achieved.
- Addition of co-substrate capable of increasing the gas yield could increase the biogas production. As observed in case of co-digestion of manure with agriculture waste, where alone manure could not prove to be much efficient.
- Provides for optimization of rheological qualities when wastes with poor fluid dynamics, aggregating wastes, particulate or bulking materials and floating wastes can be more easily digested after homogenization with dilute substrate such as sewage sludge or liquid manure.

3. CASE STUDIES

3.1. Co-digestion OFMSW with melons waste

This study was conducted to evaluate the feasibility of anaerobic co-digestion of the organic fraction of municipal solid waste (OFMSW) with melon waste (Anjum et al., 2012). The feedstock was composed of residues of mixed vegetables, fruits and other unidentified food materials which were collected from municipalities. Melons waste was collected as spoiled and discarded melons in fruit and vegetable market. The conditions for anaerobic digestion were optimized in initial experiments where different types of co-substrates including melons residues were applied with OFMSW in different concentration. Further, the effect of moisture level (60%, 70%, 80%) and inoculum (pre-digested waste) were studied. Finally, optimized treatment (30% melons + 70% crop residues at 60% moisture level) was examined for biogas potential in batch mode anaerobic bioreactors. The simple batch mode reactor was used because it is more feasible, simple and economical in performance (Parawira et al., 2004). The capacity of the anaerobic reactor was 45 kg with at organic loading rate (OLR) was 3.34 and 3.37 g VS kg^{-1} $day^{-1}$for OFMSW bioreactor and OFMSW+MW bioreactor, respectively.

3.1.1. Research Findings

It was observed that highest VS removal up to 51.6 % shown by 30% melons (300 g melons kg -1 feed) whereas at 100 g melons kg^{-1}feed gave the lowest VS removal (42.5 %) during one month process. This is because of lowest C/N (15.5) that was achieved by 300 g melons kg^{-1} feed) while a maximum value of 24.9 was observed under 100 g MW kg^{-1} feed). Alvarez et al. (2010) reported that the optimum C/N ratio for anaerobic digestion of food waste should be up to 20. It was further noted that 60 % moisture level in the system was proved to be most appropriate for biogas production from anaerobic co-digestion of OFMSW and melon residues. In study of Berriel et al. (2008), 70 % moisture level presented a stronger leachate and therefore, could produce biogas production at a high rate.

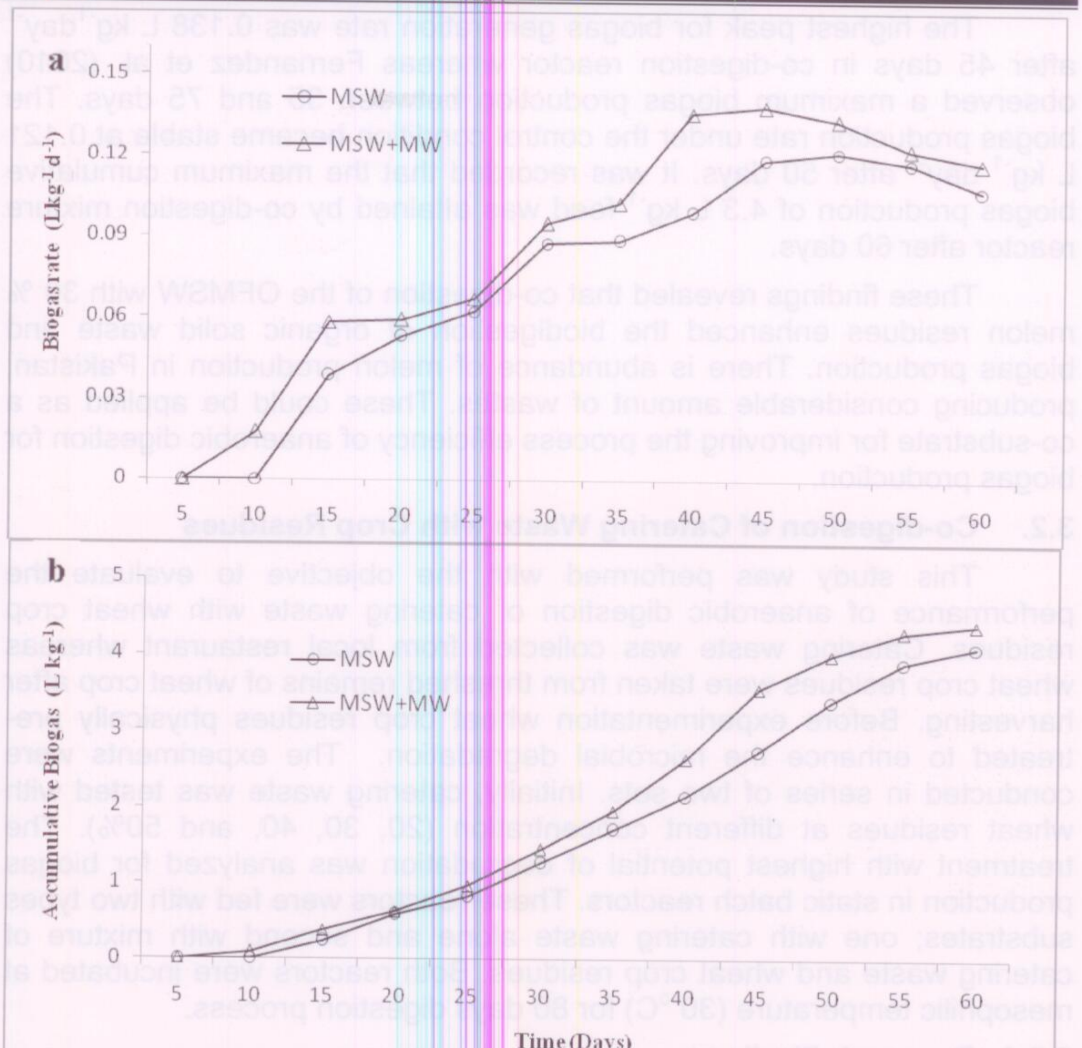

Figure 2: Biogas potential of anaerobic co-digestion of OFMSW+ MW for 60 days (a) Biogas production rate (b) accumulative biogas (modified from Anjum et al., 2012).

Figure 2 show the accumulative biogas and generation rate for 60 days process. In reactor containing mixture of OFMSW+MW (co-digestion reactor), biogas production was initiated between 5–10 days at the initial rate of 0.0175 L kg^{-1} day^{-1} while in control reactor (OFMSW alone) production was initiated between 10–15 days. After 20 days, cumulative biogas was 9.2 % greater in co-digestion reactor, which increased by 16.5 % after 25 days. Both biogas production rate and cumulative biogas continuously increased till 45–50 days in both reactors.

The highest peak for biogas generation rate was 0.138 L $kg^{-1}day^{-1}$ after 45 days in co-digestion reactor whereas Fernandez et al. (2010) observed a maximum biogas production between 35 and 75 days. The biogas production rate under the control condition became stable at 0.121 L kg^{-1} day^{-1} after 50 days. It was recorded that the maximum cumulative biogas production of 4.3 L kg^{-1} feed was attained by co-digestion mixture reactor after 60 days.

These findings revealed that co-digestion of the OFMSW with 30 % melon residues enhanced the biodigestion of organic solid waste and biogas production. There is abundance of melon production in Pakistan, producing considerable amount of wastes. These could be applied as a co-substrate for improving the process efficiency of anaerobic digestion for biogas production.

3.2. Co-digestion of Catering Waste with Crop Residues

This study was performed with the objective to evaluate the performance of anaerobic digestion of catering waste with wheat crop residues. Catering waste was collected from local restaurant whereas wheat crop residues were taken from threshed remains of wheat crop after harvesting. Before experimentation wheat crop residues physically pre-treated to enhance the microbial degradation. The experiments were conducted in series of two sets. Initially, catering waste was tested with wheat residues at different concentration (20, 30, 40, and 50%). The treatment with highest potential of degradation was analyzed for biogas production in static batch reactors. These reactors were fed with two types substrates; one with catering waste alone and second with mixture of catering waste and wheat crop residues. Both reactors were incubated at mesophilic temperature (30 ^{o}C) for 80 days digestion process.

3.2.1. Research Findings

In this work co-digestion of catering waste with pretreated wheat crop residues showed an enhanced degradation at all concentration. The initial experiments after 40 days digestion process showed that the maximum VS destruction degradation was achieved at 20% wheat crop residues treatment giving the volatile solid removal up to 39.4%. Co-digestion provides the buffering capacity and nutrients with balanced C/N ratio, on which the main factors are involving in improving degradation process (Esposito et al., 2012). Figure 3 describes the biogas generation rate and the cumulative biogas for the 80 days digestion time. It was observed that the reactor containing CW+WCR (80%+20%) was more biogas generation rate throughout the process as compared to CW alone.

The highest generation rate in case of CW+WCR was 2.10 L kg^{-1} day^{-1} at day 45 whereas maximum generation rate in CW was 1.33 L kg^{-1} day^{-1} at 57. After 63 days a gradual decrease in biogas generation rate in CW+WCR was observed and it falls to 0.75 L $kg^{-1}day^{-1}$ at day 75. At the end of experiments the cumulative biogas was up to 38% higher in CW+WCR bioreactor as compared to CW alone. Similar results were observed by Ponsa et al. (2011)where enhanced biogas production was observed in anaerobic digestion of OFMSW and cellulosic waste in ratio of 83:17. Our study demonstrate that using co-digestion technique enhanced degradation of CW can be achieved with more biogas generation. This increased biogas potential is very beneficial and could be used in future energy demand.

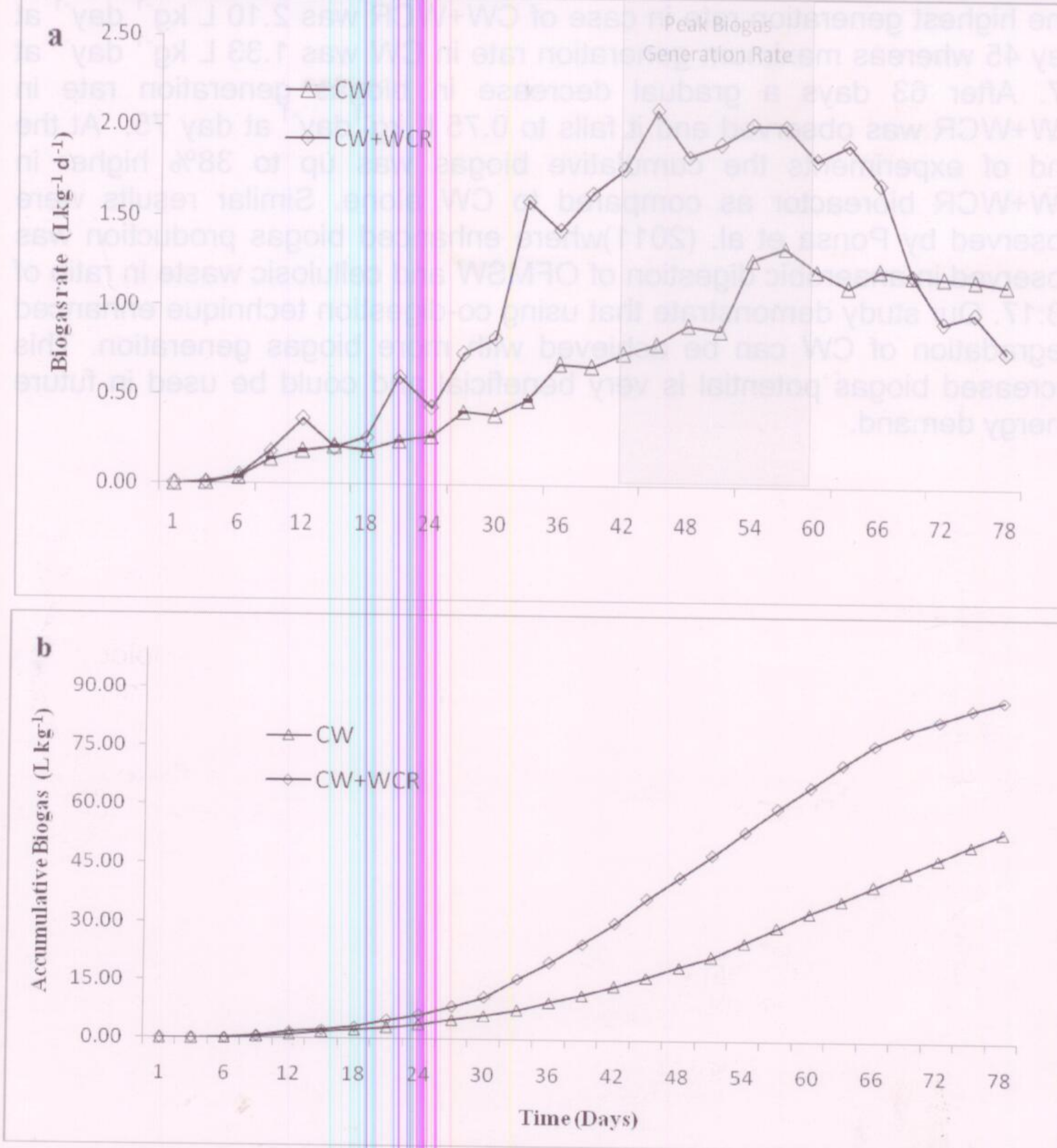

Figure 3: Biogas potential of anaerobic co-digestion of CW+ WCR for 60 days (a) Biogas production rate (b) accumulative biogas (Un-published data)

CONCLUSION

Our studies demonstrate that using co-substrates in anaerobic digestion system can establish a positive synergisms in the digester medium which improves nutrients supply and the biogas yields. In Pakistan there is plenty of food waste generated. Similarly the agrarian country produced a huge amount of crop residues every year. Using these organic wastes in anaerobic co-digestion technology could be served as an efficient alternative in future energy requirements of Pakistan. Also, this green technology aid in reducing the greenhouse gas emissions, providing a renewable energy source, and diverting the dependence on fossil fuel.

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PROSPECTS AND PERSPECTIVES OF PRECISION AGRICULTURE IN PAKISTAN

Ch. Muhammad Ashraf[1]

Hafiz Qaisar Yasin[2]

1. INTRODUCTION

Agriculture plays a vital role in the economic development of every nation, especially in the developing countries. Its sustainable growth is essential for transformation from traditional to modern economy which is interlinked with the scientific development in the sector. In fact, farming is a complex interaction of numerous factors of production depending upon their spatial and temporal variability. The process gets further complicated because of uncertainty of climatic conditions. The optimum availability of agricultural resources in terms of time and space can greatly increase farm productivity and profitability of costly inputs. The developments in modern farming technologies and techniques have brought the agriculture to a completely new level of sophistication.

Precision agriculture (PA) or precision farming (PF) is emerging as the most significant advancement with the advent of mechanization and automation of agricultural operations. There are a number of definitions and concepts in the literature pertaining to precision agriculture. For example, Robert et al., (1994) proposed *three "R"s, the right time, the right amount and the right place.* Khosla (2008) has proposed recently an *additional "R", the right manner* while defining precision agriculture. Another researcher defined PA as "*information and technology based farm management system to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of the land resource*" (Subrata et al., 2013).

The technology and various terms associated with it have been described as "*the management practice with the potential to increase profits by utilizing more precise information about agricultural resources. Further, the technology has now been developed so that field information (such as yield and application rates) can be controlled and monitored*

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about every 3 feet in the field at a reasonable cost to the farmer" (Glen et al., 2009).

The precision agriculture has also been defined as "*the application of various technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production*" (Pierce and Nowak, 1999)."and "*consideration of in-field variations in soil fertility and crop conditions and matching the agricultural inputs like seed, fertilizer, irrigation, insecticide, pesticide, etc. in order to optimize the input or maximizing the crop yield from a given quantum of input is referred to as precision agriculture*"(N. G. Shah et al., 2012).

The effectiveness and benefits of adopting PA is highly dependent on extent of spatial and temporal variability within the farm, technology usefulness, and management practices. Figure: 1 describes the benefit perspectives of precision agriculture.

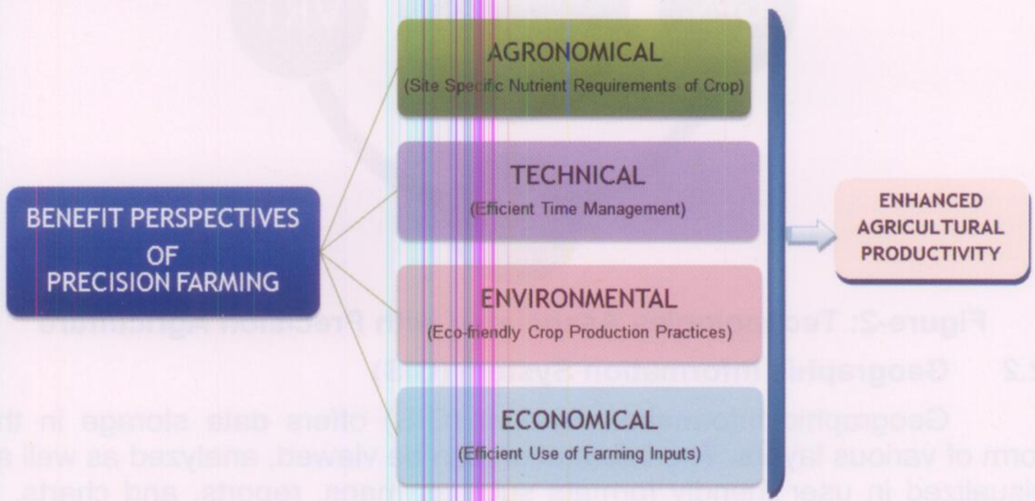


Figure-1: Benefits Perspectives of Precision Farming

2. PRECISION AGRICULTURE ENABLING TECHNOLOGIES

Precision agriculture mainly benefits from the emergence and convergence of several technologies, inter alia, including global positioning system (GPS), remote sensing (RS), geographic information system (GIS), and variable rate technology (VRT) for data gathering, information analysis, and input applications etc. The core innovations enabling PA or PF are briefly described below.

2.1 Global Positioning System (GPS)

Global positioning system (GPS) is a satellite-based navigation system, made up of a network of satellites, positioned into an orbit. GPS technology is used to accurately map boundaries and can navigate the equipment to specific locations within a pre-defined area. Its main uses in precision agriculture include field mapping, soil sampling, machinery guidance etc. One of the main usages of GPS is to identify and map the problematic areas within a field for taking site specific management decisions as well as evaluating input recommendations.

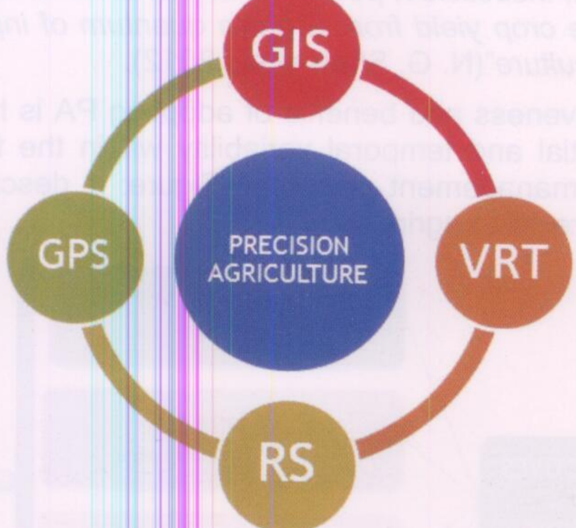


Figure-2: Technologies Associated with Precision Agriculture

2.2 Geographic Information System (GIS)

Geographic Information System (GIS) offers data storage in the form of various layers. The information can be viewed, analyzed as well as visualized in user friendly formats such as maps, reports, and charts. A tremendous amount of information pertaining to field topography, soil properties, water absorption, nutrient levels, yield variation etc. can be assessed and management decisions are, accordingly, made to improve productivity in the problematic areas.

2.3 Remote Sensing (RS)

Remote sensing (RS) technique is used for obtaining information about objects through special instruments that are not in physical contact with the entities under observation by means of capturing the electromagnetic energy reflected from features. The RS imagery has many applications in mapping land-use & cover, agriculture, soil maps, and forestry. Remotely sensed images can be employed for identifying plant populations, nutrient deficiencies, water scarcity or surplus, plant diseases, weed infestations, insect damages etc.

2.1 Variable Rate Technology (VRT)

Variable rate technology (VRT) includes computer controllers and associated hardware to vary the application rate of various agriculture inputs. The GPS controls the location of the machinery in the field, which is linked with the GIS to communicate the controller about site specific field characteristics of various spots. The pre-determined yield goals then dictate the precise requirement of nutrients at specific locations. The controller then manipulates the apparatus to apply the correct amount of inputs.

3. IMPACT OF PRECISION FARMING ON AGRICULTURE

About 73 percent of the studies carried out on profitability of precision agriculture technologies have concluded that its adoption was profitable (Lowenberg-DeBoer, 2000). The use of PF has decreased the average input application, increased yield and maximized the profit margin as well as reduced negative environmental impacts of crop production by using inputs more efficiently (Lowenberg-DeBoeret al., 2000; Larkin et al. 2005; Michael et al., 2007; Man Yu et al., 2003).

The economic benefits of precision agriculture on six farms from the Australian wheat belt covering a range of agro-climatic regions, cropping systems, farm sizes, soil types, and production levels have revealed that annual benefits of PA ranged from $14 to $30 per hectare excluding capital costs. The break even analysis showed that initial capital outlay was recovered within 2 to 5 years. Other benefits reported were less soil compaction, low energy use, less labour requirement and timely sowing. Moreover, the opportunity to conduct on farm trials, increased knowledge of paddock variability, better confidence in varying fertilizer rates, and improved weed control due to shielded spraying were among the intangible benefits (Michael et al., 2007).

The precision farming practices in cotton increased its yield by an additional 0.44 pounds per acre for every pound of nitrogen fertilizer use compared to conventional practices. Overall, this analysis has shown that spatial application of nutrients as compared to conventional whole farm basis resulted in increase crop yield, net revenue, and productivity on a per acre basis(Man Yu et al., 2003).The implementation of variable rate technology in citrus has resulted in 30 percent reduction of chemicals and 40 percent decrease in fertilizers (Ehsani, et al., 2009).

The economic and ecological benefits through site specific weed control with a GPS guided sprayer were enormous. On an average about

54 percent of the herbicides were saved. For grass weed herbicides, the savings were 90 percent in winter cereals, 78 percent in maize, and 36 percent in sugar beet. For herbicides against broadleaf weeds, 60 percent were saved in winter cereals, 11 percent in maize, and 41 percent in sugar beet against conventional practices(C. Timmermann et al., 2003).

The estimation of farm energy savings in terms of fuel and time by using GPS guidance and/or autosteering systems in farm vehicles in the Upper-Midwest region of the USA has revealed that there is good adoption of precision agricultural technology in the region. The results indicated that 34 percent of farms saved 6 percent of time and 6.32 percent of fuel by using GPS guidance systems. The study further showed that 27 percent of farms used autosteering systems that saved 5.75 percent of time and 5.33 percent of fuel (Bora et al., 2012).

4. ADOPTION TRENDS OF PRECISION AGRICULTURE

The global positioning system is the pivotal technology that drove the development of PA concept in the late 1970s. After the inception of precision agriculture in 1980s, its modern practice started in the early 1990's when first GPS became available for commercial use.Subsequently, GPS technologies emerged quickly to map agricultural farms comprehensively as well as apply inputs in precise amounts and at exact time using variable rate technology. Later on, introduction of GPS linked yield monitors enabled revealing the vast variability of farms while auto guidance helped steering the equipment more accurately. Most recently, a variety of sensors have been developed to quickly assess the input (water, nutrients etc.) levels in soils as well as plants.

At present, precision farming is adopted in numerous countries around the globe. Despite unprecedented growth of PA technologies in the last decade, its geographic and temporal adoption has, however, been uneven in the United States, Germany and Canada. Argentina, Brazil and some East Asian countries have also adopted these practices to a considerable extent.The adoption of PA in developing countries is actually different from those who invented the technology. One of the reasons for low adoption is its complexity as it involves a set of tools, each with a specific purpose. The farmers may opt only one or two PA technologies for evaluation of their impacts before adopting complete package.

The number and diversity of manuscripts published in international journals in the domain of PA as well as the variety of research papers presented at major international conferences in different countries around the world is, indeed, a reflection of its development and emergent propagation. The researchers including Khanna, M. (2001), Fountas et al., (2005) and Walton et al., (2010) have recently investigated the worldwide adoption of precision agriculture.

A countrywide survey for over 8,400 farms in the United States has revealed that only 25 percent of farmers were aware of PA technologies, less than 5 percent adopted some aspects of PA and nearly 70 percent were completely unaware of precision agriculture (Daberkow & McBride, 2000).

The adoption of PA technologies was higher among farmers having greater yield variation within the field and using computers for management decisions. Furthermore, the number of PA technologies employed by the producers has positive correlation with their educational level and negatively correlated with the operator age. Younger and educated farmers have adopted large number of precision agriculture technologies (Kenneth et al., 2011).

An analysis of productivity difference between precision and conventional farming has revealed that adoption of PF enhanced tomato yield up to 80 percent and 34 percent in brinjal. Increase in gross margins was, however, reported as 165 and 67 percent in tomato and brinjal, respectively. The results further indicated that if probability of adoption increases by 10 percent, net returns increase by 39 percent and 28 percent in tomato and brinjal cultivation, respectively. Lack of finance and credit facilities have been identified as the major constrains in non-adoption of precision farming (R. Maheshwari et al., 2008).

The farmer interviews at several agricultural exhibitions in Germany have revealed that roughly half the interviewed farmers knew about PF, 6.65 to 11 percent have used PF techniques, and about 7 to 10 percent intended to start PF in the future. The results also indicated that a large number of farmers did not even know the meaning of precision farming (M. Reichardt et al., 2009).

A study carried out to investigate various technologies, allied benefits, opportunities, challenges as well as difficulties encountered by precision farming has revealed that PA enabled farmers to integrate and take control of production processes with the purpose to increase farm profitability and reduce risks. Although benefits of PA are commonly agreed, there are still a significant number of obstacles hindering its further development and adoption by majority of farmers. The technology has a great potential and large manned machines may be replaced by small autonomous robots in near future leading to a paradigm shift in agricultural production. The study also pointed out that the growth of PA is unprecedented during last decade especially in countries such as United States, Germany, Canada and Australia. Its adoption in rest of the world is, however, relatively slow. Lastly, the adoption of PA is currently in a stationary phase between the early adopters and the majority (A. A. Bakhtiari and A. Hematian, 2013).

The adoption of PF technologies is likely to follow a normal distribution with innovators and early adopters as the first to adopt the technology (Lamb et al., 2008). In other hand, land tenure, age, and computer use ability had a significant impact on farmer's perceptions regarding importance of precision agriculture (Torbett et al., 2007).Furthermore, older farmers are less likely to invest resources in obtaining PF information without the certainty of receiving returns on their investment in short run (Banerjee et al., 2008).

5. PERSPECTIVE AND PROSPECTS OF PRECISION AGRICULTURE IN PAKISTAN

The conventional precision agriculture is generally practical where land holdings are large, labour is expensive, and there is a great degree of inter and intra field variability. In Pakistan's perspective, where the average land holdings are small (58 % farmers own less than 5 acres), inputs cost are high, crop yields are low, water resources are dwindling, PA may be considered as the accurate application of agriculture inputs for enhancing crop productivity. Among all factors of agricultural production, water is the most critical and precious input. The crop yields in Pakistan are far lower than their potential mainly because of inefficient utilization of this vital resource.

An analysis of Pakistan's water budget (Figure-3) reveals that huge volume of water is wasted in the distribution network of main/branch canals, distributries, minors, and tertiary conveyance system comprising of about 145,000 watercourses. The surface water available at the farm gate is 50 million acre feet (MAF), which is grossly insufficient for sustainable irrigated agriculture. A substantial amount of irrigation water (32 MAF) is also lost during its application due to uneven fields and poor farm designs. This deficiency is, however, compensated to a great extent by groundwater abstractions of almost 42 MAF, which is infact over exploitation of this vital resource as recharge to freshwater areas is only 23 MAF. Such an unsustainable groundwater pumpage is causing mining of aquifers leading to intrusion of saline water into adjoining freshwater areas. In nutshell, about 73 MAF water remains available for crop use against 98 MAF of irrigation requirements. As such, there exists a gap of nearly 25 MAF to meet crop water requirements for present cropping intensity of 155 percent.

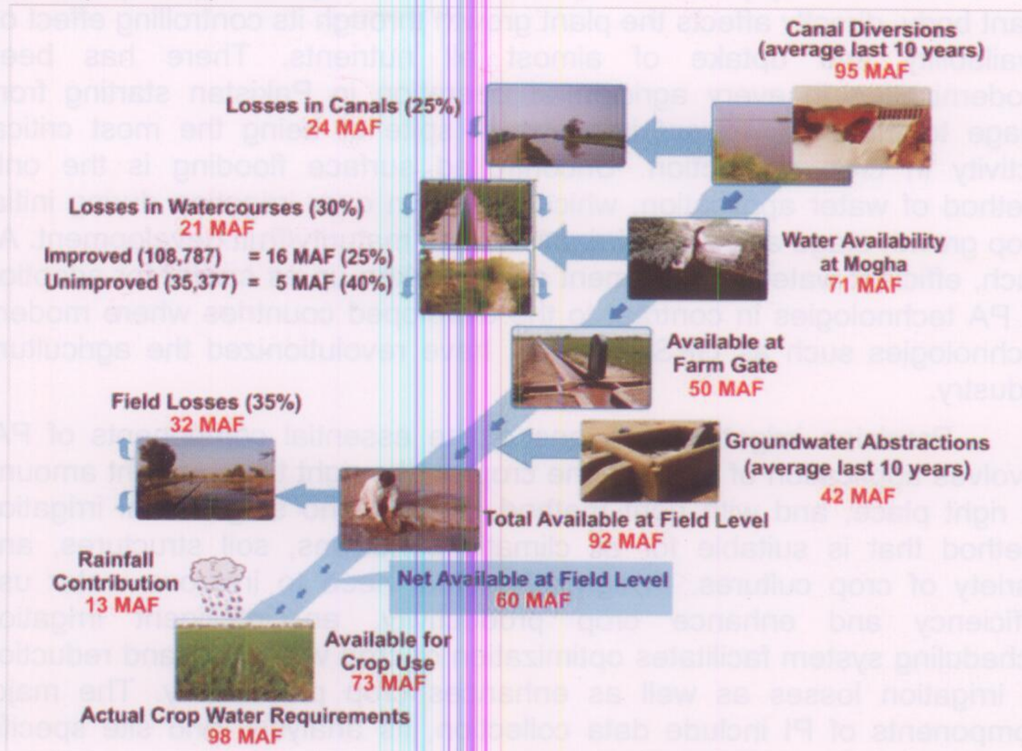


Figure-3: Pakistan Water Budget

It is evident from the above that *WATER NOT LAND* is limiting factor in agricultural production of the country. The focus should, therefore, now be shifted to produce more per unit of water rather than conventional term of yield i.e. production per unit of land.

Figure-4: Concept of Producing More Crop per Drop

In fact, the soil moisture is highly variable component of the soil environment in crop production. Water, constituting virtually 90 percent of plant body, directly affects the plant growth through its controlling effect on availability and uptake of almost all nutrients. There has been modernization in every agricultural operation in Pakistan starting from tillage to threshing except irrigation in spite of being the most critical activity in crop production. Uncontrolled surface flooding is the only method of water application, which results in over irrigation during initial crop growth stage and under irrigation at its maturity/fruit development. As such, efficient water management can be taken up as carrier for adoption of PA technologies in contrast to the developed countries where modern technologies such as GPS, GIS etc. have revolutionized the agriculture industry.

Precision irrigation (PI), one of the essential components of PA, involves application of water to the crop on the right time, in right amount, at right place, and with right method. There is no single ideal irrigation method that is suitable for all climatic conditions, soil structures, and variety of crop cultures. In light of factual need to improve water use efficiency and enhance crop productivity, an intelligent irrigation scheduling system facilitates optimization of crop water use and reduction in irrigation losses as well as enhances crop productivity. The major components of PI include data collection, its analysis, and site specific control as shown in Figure 5.

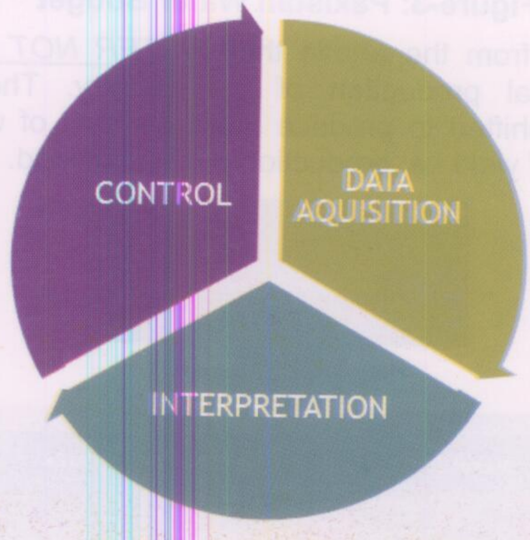


Figure-5: Components of Precision Irrigation System

5.1 Efficient Irrigation Techniques and Technologies

Uncontrolled surface flooding is the mostly used irrigation method in Pakistan due to its lower costs. This is, however, an inefficient practice resulting excessive water losses through, deep percolation and evaporation from farm channels as well as in the fields. There has been many advancements in irrigation conveyance and application systems that substantially increase the irrigation efficiency e.g. development of drip and sprinkler systems.

Drip irrigation system has become the most significant innovation that allows controlled rather spoon-feed water and nutrients directly to plant's root zone. The technology is versatile in its applicability and provides complete control in irrigation operations. A comparative pattern of moisture availability to crops under different irrigation methods shows that drip irrigation is the only method that maintains soil moisture contents as close to the field capacity as possible (required for optimum crop growth) viz-a-viz conventional/traditional systems(Figure-6).

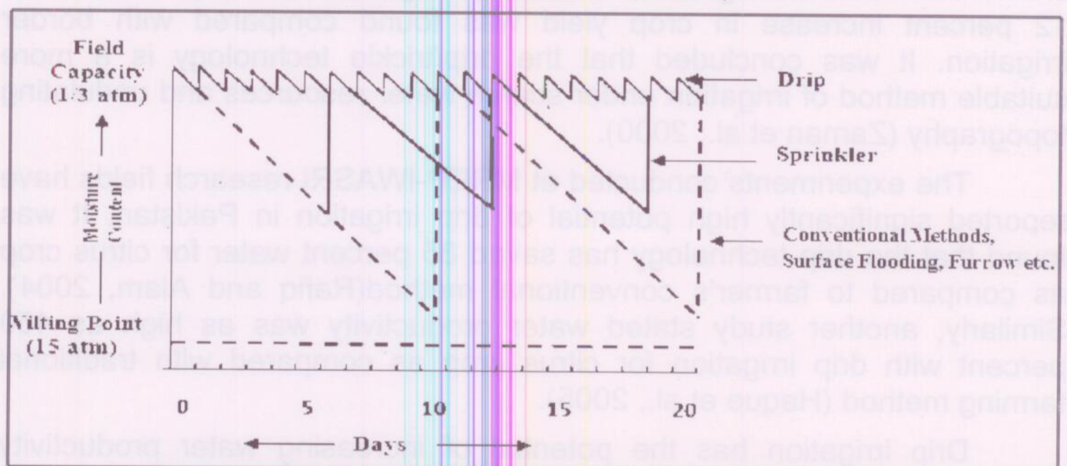


Figure-6: Soil Moisture Availability to Plants under Different Irrigation Methods

The research conducted on drip irrigation has shown palpable results in terms of water savings, enhancing crop productivity, and improving produce quality. The same has been expounded in the flowing literature review.

The drip irrigated apple orchard yielded earlier and nine times higher as compared with sprinkler irrigation (Middleton et al., 1979). Water saving was 42-60 and 12-74 percent for Kharif and Rabi vegetables, respectively compared with furrow (conventional) irrigation method (Chang and Marri, 1988). According to CWC (1991), the efficiency of drip irrigation system was over 90 percent as compared to about 30-50 percent in case of conventional irrigation method. The saving in irrigation water was 27 and 59.8 percent for tomato and sugarcane, respectively when compared with conventional method.

The evaluation of advanced irrigation application techniques has revealed 80 percent water saving in case of drip irrigation in Pakistan (Ahmad and Ahmad, 1993).The drip irrigation could be 50 percent more water efficient as compared to surface irrigation systems (Moshabbir et al., 1993). The use of drip technology resulted in water saving and yield increase upto 40-70 and 10-100 percent respectively (INCID, 1994). Drip irrigation has resulted in increased water use efficiency and greater yields than the conventional furrow irrigation (Yohannes and Tadesse, 1998).

A research study carried out to find out the potential of water saving and crop yield using modern irrigation methods in semi-arid areas has shown that water saving under trickle/drip irrigation was 34 percent, while 12 percent increase in crop yield was found compared with border irrigation. It was concluded that the drip/trickle technology is a more suitable method of irrigation under scarce water resources and undulating topography (Zaman et al., 2000).

The experiments conducted at MREP-IWASRI research fields have reported significantly high potential of drip irrigation in Pakistan. It was found that the drip technology has saved 85 percent water for citrus crop as compared to farmer's conventional method(Rafiq and Alam, 2004). Similarly, another study stated water productivity was as high as 450 percent with drip irrigation for citrus crop as compared with traditional farming method (Haque et al., 2005).

Drip irrigation has the potential of increasing water productivity even under deficit irrigation environment. The deficit irrigation of 30 percent (D30) and 15 percent (D15), produced cotton yields of 2,078 and 2,862 kg ha^{-1}, respectively in comparison to 3,112 kg ha^{-1} for no deficit (D0). The water use efficiency was 0.61, 0.64, and 0.55 kg m^{-3} for D0, D15, and D30 respectively. It was concluded that D15treatment have resulted in better water productivity in water stressed areas (Bakhsh et al., 2008). Additionally, a saving of water and energy in case of drip/trickle irrigation compared with conventional irrigation system and found that water saving was 50, 47 and 43 percent for cotton, sugarcane and chillies, respectively. Moreover, energy saving per acre was 26 percent in cotton, 22 percent in sugarcane, and 25 percent in chillies (Tahira, 2010).

5.2 Precision Application of Nutrients

The plant requires a balanced supply of nutrients throughout its growing period. It is indicated in Figure-7 that these requirements are low during early growth stages and then increase towards fruiting stage where nutrient management becomes the most critical. For example, phosphorous (P), although required in small amounts, but is needed throughout the crop growth period. Contrarily, nitrogen and potash are required in small quantities at initial and final stages of plant growth but they are needed maximum in mid of crop devolvement. According to the present application methods, all phosphorous and potash is applied before planting as base dose. The nitrogen is, however, supplied in split doses. The drip irrigation, however, enables provision of these fertilizers in exact dosages accordingly to crop growth stage. This precise application of nutrients is called fertigation, which results in improved fertilizer use efficiency, flexibility in timing of application as per crop demand, increased yields, and improved quality of the produce as well as saving in labour.

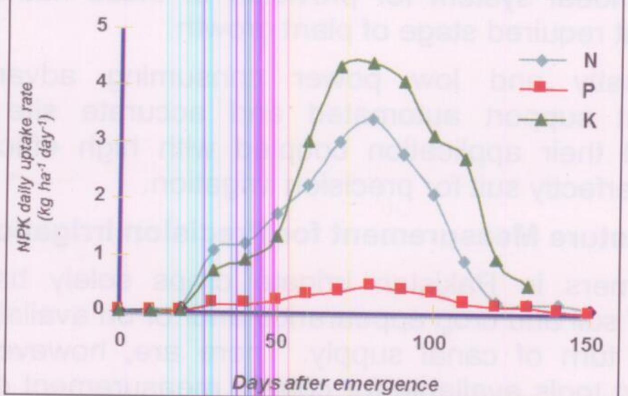


Figure-7: Typical Curve of Nutrient Uptake Rate of Crops

In addition, plants also require micronutrient in small amounts to meet their nutritional needs and growth maximization. Their deficiency as well as excessive uptake both can effect crop development and reduce yield. The main micronutrients are Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), and Zinc (Zn). According to the famous "Law of the Minimum" developed by a renowned researcher Justus von Liebig in 1940, "*the growth is controlled not by the total amount of resources available, but by the scarcest resource (limiting factor)*". This principal can be summed up in a way that the availability of the most abundant nutrient in the soil is only as good as the least abundant (Alexander N. G. et al., 2010).

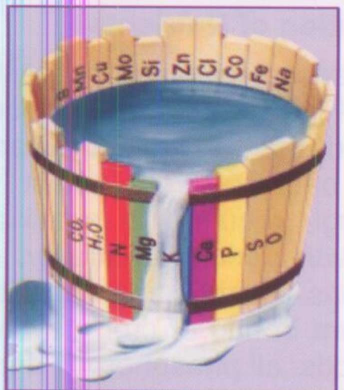


Figure-8: Concept of Law of the Minimum

Micronutrients are generally applied in the form of chelates, which are used as carriers for micronutrients to keep them in solution form as well as protect them from reactions with other nutrients that cause the micronutrients to become insoluble and unavailable to the plants. The drip irrigation is an ideal system for provision of these nutrients in precise quantities and at required stage of plant growth.

Less costly and low power consuming advanced irrigation techniques that support automated and accurate site specific input scheduling and their application coupled with high efficiency irrigation systems may perfectly suit for precision irrigation.

5.3 Soil Moisture Measurement for Precision Irrigation

The farmers in Pakistan irrigate crops solely based on visual observations of soil and crop appearance and/ or on availability of water at their rotational turn of canal supply. There are, however, a numerous instruments and tools available for correct measurement of soil moisture. The use of these devices can remove the guess work in irrigation management by providing an accurate assessment of the soil water status. There are numerous such devices used for moisture measurement such as weather stations, tensiometers, gypsum blocks, neutron probes, capacitance devices, soil moisture sensors, time domain reflectometry, time delay transmission, Full Stop - wetting front detection, shovel / dig stick. A brief overview of commonly used low cost and farmers-friendly soil moisture monitoring tools is outlined below.

5.3.1 Time Domain Reflectometry

Time Domain Reflectometry (TRD) is a proven technology for quickly and accurately determining volumetric soil moisture content. It is based on recording the propagation time of an electromagnetic pulse along measuring pins buried in the soil, which in turn is linked to soil moisture content. The meter's built-in data logger can automatically record readings from several sites as well as capture geo-referenced statistics that can be readily imported into software for full analysis mapping of relative water content at multiple sites.

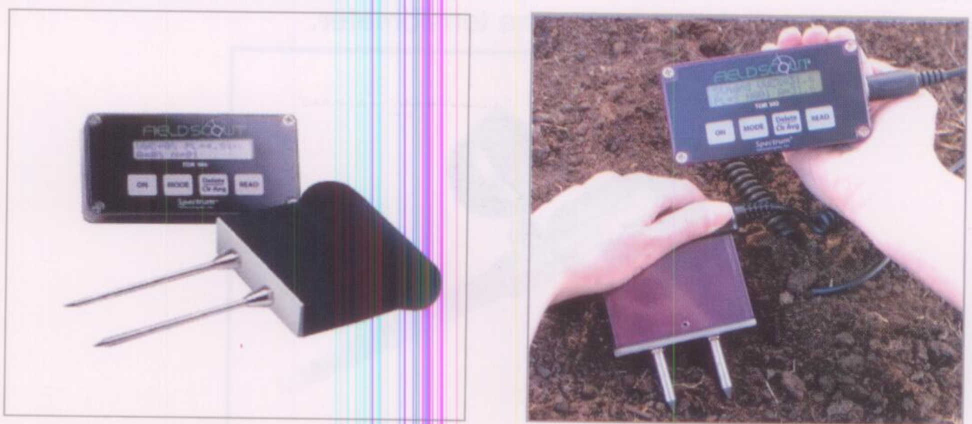


Figure-9: TDR Meter

5.3.2 ECHO Soil Moisture Sensors and Meter

The ECHO probe monitors soil moisture levels using the capacitance principle. It is comprised of low-cost sensors made of durable porous materials for measuring volumetric soil moisture content over a wide geographic area.

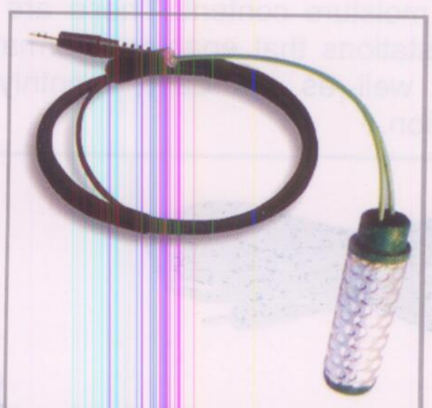


Figure-10: ECHO Soil Moisture Sensor and Meter

5.3.3 Tensiometer

A tensiometer is a cylindrical pipe with a porous ceramic cup attached to one end and a vacuum gauge to the other with a reservoir located at the top. The tube is filled with water that is sealed tightly preventing air entry to ensure proper working. As soil dries, it tries to extract water through the ceramic tip that creates a vacuum within the tube indicating decrease in soil moisture content and vice versa. These phenomena are calibrated to represent soil moisture status and are measured on the dial attached to the tensiometer.

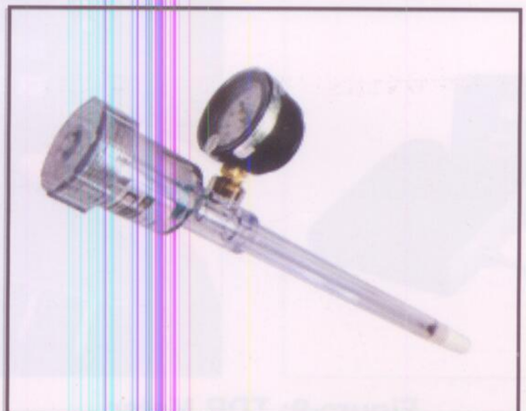


Figure-11: Tensiometer

5.3.4 Soil Moisture Sensors

The soil moisture sensors combine affordability and accuracy. These are composed of two electrodes embedded in a suitable porous medium.Changes in electric current are detected by the sensors and correlated to the soil moisture content. These are compatible with data loggers and weather stations that enables information view in graphical and tabular form as well as run daily, monthly, and yearly reports customized to application.

Figure-12: Soil Moisture Sensors

5.3.5 Electrical Resistance Blocks

Electrical resistance or gypsum blocks consist of two parallel rectangular or cylindrical matchbox size pieces made of gypsum embedded with electrodes. These blocks are buried in the field and the electrical resistance between the electrodes, which is inversely proportional to its surrounding soil water content, is measured with a digital meter. When soil is wet, water is drawn into the block and indicates low resistance. As soil dries, water is drawn from it to adjoining soil and higher reading of resistance between the electrodes is indicated on meter.

Figure-13: Electrical Resistance Blocks

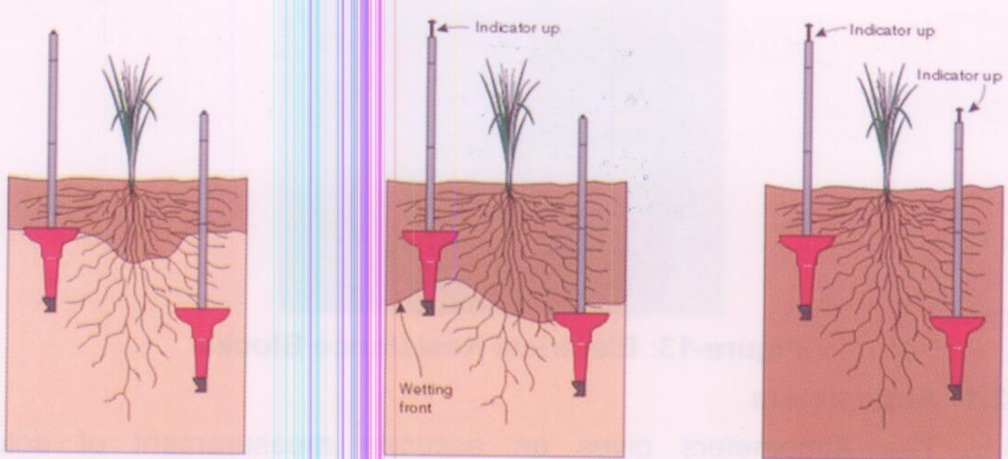
5.3.1 Atmometers

The Atmometers gives an accurate measurement of actual evapotranspiration (ET) at any field location. The ET readings are made directly from the site tube mounted in front of a ruler eliminating the use of any electronic equipment or computer interface. The crop evapotranspiration is an effective tool for scheduling irrigation, especially when combined with a program of soil moisture measurement.

Figure-14: Atmometers

5.3.7 Full Stop (Wetting Front Detector)

The wetting front detector (WFD), which is registered as "Full Stop", was developed in response to low adoption of existing soil moisture measuring tools for improving the accuracy of irrigation and assisting in fertilizer and salt management as well as detecting waterlogging. It is basically a switch that indicates passing a wetting front through a given depth in the root zone. The downward moving water through the root zone converges inside a specially shaped funnel. As the soil at the base becomes so wet that water seeps out of it, passes through a filter and is collected in a reservoir activating a float that in turn triggers a red indicator flag above the soil surface. It is relatively a simple, low-cost, and interactive tool with no electronics involved for aiding accurate irrigation scheduling.



Too Little Water	About Right (Desired Result)	Too Much Water
Shallow Indicator: DOWN **Deep Indicator: DOWN** If neither indicator is triggered, then watering is generally too shallow.	**Shallow Indicator: UP** **Deep Indicator: DOWN** Water has moved past the shallow detector to the lower part of the root zone.	**Shallow Indicator: UP** **Deep Indicator: UP** The deep indicator should be triggered only when it is necessary to fill the whole root zone.

Figure-15: Wetting Front Detector

6. CHALLENGES AND PROBLEMS

The adoption of PA or PI is at nascent stage in Pakistan. For example, the installation of drip and sprinkler irrigation covers only a fraction of a percent of total cultivated land of the country.Their adoption/promotion, however, requires extensive mass awareness involving a complete paradigm shift from archaic traditional flood irrigation method and associated agricultural practices. Considering the benefits of PA in terms of inputs saving and productivity increase, the gross benefits would be enormous. The major challenges hindering its adoption are described here under.

6.1 High Investment Cost

Precision irrigation or PA is capital intensive in initial cost, which is one of the major reasons that the farmers are reluctant to adopt especially in developing countries. The active participation of all stakeholders i.e. government, financial institutions, agriculture industry, farmers, private sector and NGOs are required to collaborate for mobilizing initial investments, particularly for small farmers. Moreover, adequate financial resources should be arranged for complete technology transfer and provision of follow-up assistance for successful crop cultivation through precision irrigation.

6.2 Enabling Environment

As the technology is nascent, the continuity of government policies and financial support is much essential to build confidence of service providers for assured sizeable market/clientage. Moreover relaxation in taxes on input and supply of PI equipment may help to make the technologies cost effective and affordable. The same will create enabling environment for industry to start local manufacturing of PI components for technology indigenization and making it affordable for small farmers who are in majority.

6.3 Research Support

Applied research and development (R&D) activities are needed for indigenization of precision irrigation technologies including HEIS and soil moisture measurement/moisture tools through pilot testing, modifications and evaluations to test local conditions. The experts, consultants, and scientists from institutions such as Pakistan Agricultural Research Council (PARC), Islamabad; Water Management Research Center (WMRC), University of Agriculture, Faisalabad; Arid Agricultural University, Rawalpindi; Alternate Energy Development Board; Ayub Agricultural Research Institute, Faisalabad; International Water Management Institute, Lahore; Pakistan Council for Renewable Energy Technology, Islamabad etc. may coordinate to accelerate technology adoption.

6.4 Capacity Building

Adequate training and capacity building of various stakeholders is imperative for successful adoption of new and challenging technologies like HEIS. The diversity of interventions, currently unfamiliar to the technical staff as well as the farming community requires extensive trainings to build their capacity about latest irrigation advancements and improvements.

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Future Food Challenges for Pakistan: Pothwar as Impending Resource for Food Security

Ghulam Nabi[1], Muhammad Ashraf[2], and Muhammad Masood[3]

ABSTRACT

Pakistan ranks at fifth in top ten wheat growing countries of the world. Wheat is grown on 9.4 million hectare with 2.4 million metric ton yield. There are two main agricultural areas, irrigated and rainfed. In the past much emphasis was given on irrigated areas whereas rainfed areas were almost ignored. The rainfed area comprises 12 Mha (66% of total agricultural area) that contributes only 10% in agricultural production. This contribution is further reduced if there is insufficient rain during crop growing. For example, during Rabi cropping (October-March) 2000-2001, when the rainfall was very small (62mm), the contribution of wheat from rainfed or dry areas of the Punjab to the total production in the country was only 3% with an average yield of 505 kg ha^{-1}. In reverse of that whenever there are sufficient rains in rainfed or dry areas, bumper crops are produced, same has been observed in year 2013.There are different techniques for rain water harvesting i.e., small dam, storage pond, moisture conservation etc., most), mostof them are time consuming and cost effective.

The Pothwar plateau comprises the districts of Rawalpindi, Attock, Jhelum and Chakwal, and it forms about 40% of the Punjab Barani (rainfed) areas. In this study probability analysis of rainfall data of district Chakwal was done to assess maximum chance of rainfall available for sowing of wheat crop. Based on the results it is proposed that wheat crop should be planted in 1st and 2nd week of November or 1st week of December. It is further proven that soils of the Barani areas are virgin, fertile and are capable of producing high intensity crops. Lesser efforts

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can bring better results as compared to irrigated areas of the country that have already attained a high level of intensity and yields.

INTRODUCTION

About 80% of the world's agricultural land is rainfed, and contributes at least two-thirds of global food production (Oweis and Hachum, 2006) while about 70% of the world's poor people live in these areas where livelihood options outside agriculture are limited. The Indus plain is the most prosperous agricultural region of the country.

The population growing rate of Pakistan is 2% per annum whereas the average annual growth rates in wheat area, yield and production for the past 10 years (1995-1996 to 2005-2006) were 0.1 %, 2% and 2% respectively. But during the last five years (1999-2000 to 2004-2005) wheat production grew at an annual rate of just 0.4%. The country is therefore heading into a difficult situation unless these downward trends are arrested. Average wheat yield in Pakistan is about 2.6 ton ha^{-1}. However, there are farmers harvesting twice the national average, and even some farmers harvesting 6-7 ton ha^{-1}. The record harvest yield in 2005 was 7.8 ton ha^{-1}. Yet the nation is treading a difficult path between deficits and marginal surpluses.

The geographic area of Pakistan is about 80 million hectares (Mha), of which 18 Mha is irrigated and dry land farming is practiced on 12 Mha. The Barani (rainfed) areas of Punjab cover about 7 Mha and are home to over 19 million people. The average annual rainfall ranges from over 1000 mm in the northeast to less than 200 mm in the southwest. These areas, however, contribute less than 10% to total agricultural production and depend solely on the rainfall. This contribution is further reduced if the rainfall is insufficient and occurs at inappropriate times. For example, during Rabi cropping (October-March) 2000-2001, when the rainfall was very small (62mm), the contribution of wheat from Barani Punjab to the total production in the country was only 3% with an average yield of 505 kg ha^{-1}(MINFAL, 2009). It was a similar case with other crops. Therefore, the average yields of major crops are far below what is achievable. The major constraints which contribute to low agricultural productivity are low and erratic rainfall, causing stress at critical growth stages.

The Pothwar area main rainfed tract extends over 2.23 Mha in the north and central part of Punjab, whose elevation ranges from 457 to 610 m above mean sea level (msl). The Pothwar plateau comprises the districts of Rawalpindi, Attock, Jhelum and Chakwal, and it forms about

40% of the Punjab Barani (rainfed) areas(Fig.1). The main landuse are light and heavy vegetation, hilly area, water bodies and other infrastructures.

The erosion and water losses are main factors that hinder the agriculture productions. The total water potential on Pothwar region is about 3.50 million acre feet (MAF), only 20% is utilized through water conservation practices (Small dams, storage ponds etc.). There are about 55 small dams and large number of storage ponds. On the average 2.87 MAF water passed away through Soan Basin without any use. The need of time is efficiently conserve all the surplus water during monsoon season and utilize it by efficient irrigation practices, including high efficiency irrigation system (Drip, Sprinkler etc.), although a few farmers are using these by technical and financial assistance of Government, but it should be extended to common stalk holder.

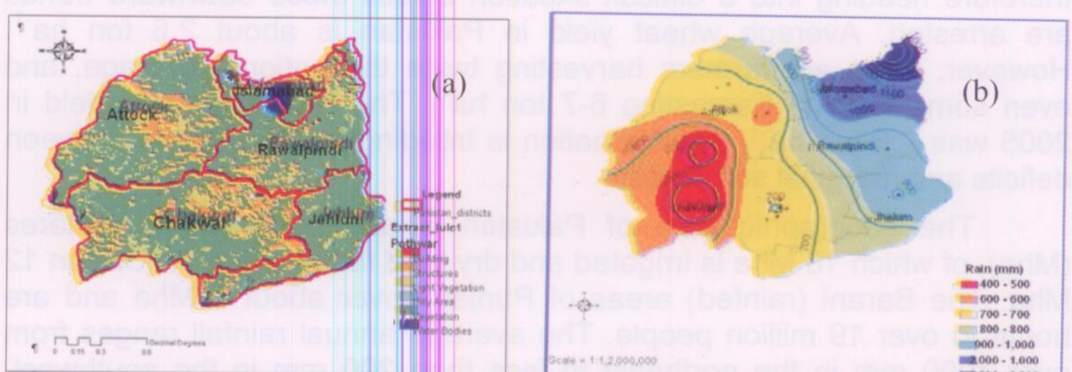


Fig. 1 a) Map of Pothwar area b) rainfall distribution in Pothwar

Soil Conditions in Pothwar

The topography of Pothwar is hilly, soil mainly affected by gully erosion; some of the gullies are wider than medium size rivers. The farmers use gullied and terraced land for crop production. The soil of Pothwar area is highly productive for crop growth if irrigation water is available. The soil characteristics are shown in Table-1.

Table-1 Soil characteristics of Pothwar

Parameter	Year 2001-02	Year 2002-03	Year 2003-04
ECe (dS/m^{-1})	1.19	1.05	1.38
PH	7.78	7.7.	7.82
Organic Matter (%)	0.61	0.36	0.44
Extractable K ($mg\ kg^{-1}$)	118.0	111.0	90.0
Available P ($mg\ kg^{-1}$)	5.0	6.40	7.10
Texture class	Sandy Loam	Sandy Loam	Sandy Loam

Source: Rashid et al. 2008

The main Rabi (October to March) crops in the area are wheat, gram, lentil and mustard and Kharif (April to September) crops include maize, jowar, bajra, pulses and groundnuts. The cropyields are generally less than half of those achieved with controlled irrigation. There are a large number of water conservation structures i.e., small dams, check dams, small ponds etc., if stored water is used through high efficiency irrigation system (drip, sprinkler etc.) the yield can be increased two to three times.

Proper selection of crops, management of soil, rainwater harvesting, soil moisture conservations, and supplement irrigation are the key factors to improving the land and water productivity and livelihoods of these areas (Albeyi et al., 2006; Passioura, 2006; Rockstorm and Falkenmark, 2000).

Tillage Practices

The tillage practice and crop rotation system have also an impact on crop yield, tillage practice are used for moisture conservation. Under normal practice the farmers cultivate their field a number of times to conserve moisture during the monsoon season, the same moisture is used for germination of wheat crop if timely rainfall is not available. Same was observed by ICARDA-2011, (Table 2). The fallow wheat cropping system has highest yield (1575 kg ha^{-1}) followed by maiz-wheat (1341 kg ha^{-1}) and mungbean-wheat (703 kg ha^{-1}).

Table 2 Cropping system, tillage practices and annual wheat yield (kg ha^{-1})

Cropping System	Tillage Practice		
	Cultivator	Moldboard	Average
Fallow-wheat	1575	1677	1626
Maize-wheat	1341	1475	1408
Mungbean-wheat	703	827	765

Source: ICARDA, 2012

In case of tillage practices the moldboard has more yields as compared to normal cultivator chisel plow. Gypsum application helps to improve moisture holding capacity of soil, gypsum has been provided to the farmers by different Government organizations such as Soil and Water Conservation Research Institute (SAWCRI), and Barani Agricultural Research Institute (BARI) on subsidized rate. (Rashid et.al., 2008) studied the role of gypsum in moisture conservation. Three year data from 2001-2 to 2003-4 was collected. The monthly rainfall data was also collected it as shown in Fig 2.

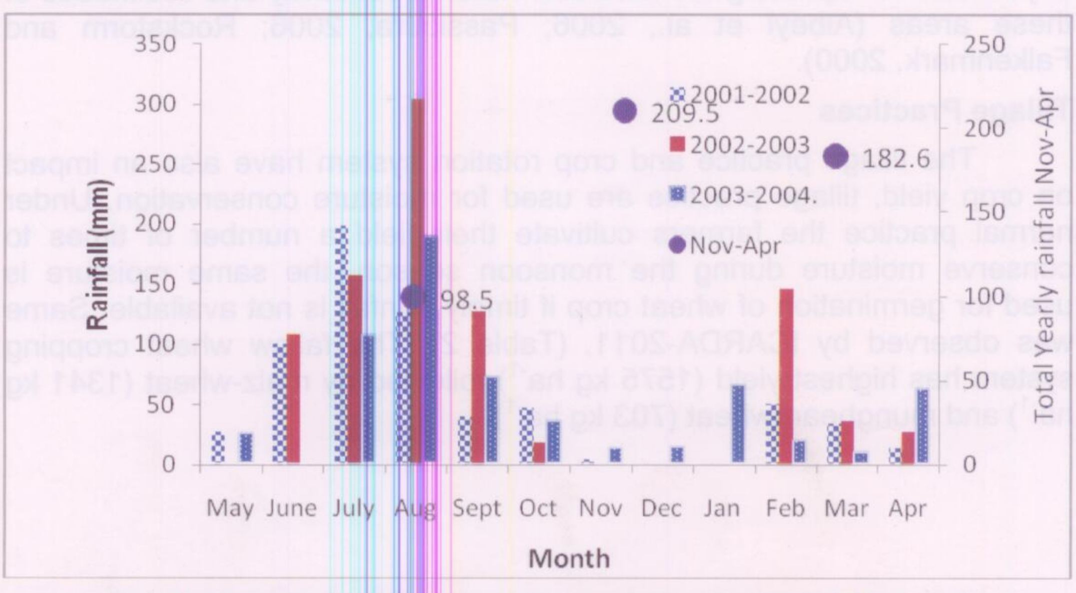


Fig 2. Monthly and six month rainfall pattern in Chakwal 2001 to 2004.

The monthly rainfall varied from 0 mm to 303 mm in August 2003. Fig.2 shows that maximum rainfall occurred in July to Sept. On yearly basis 2003 is most wet year total rainfall 917 mm whereas rainfall in 2001 and 2002 was 668mm and 608 mm respectively. Total six monthly (Nov-Apr) rainfall for 2001, 2002 and 2003 was 98.5mm, 209 mm and 182 mm respectively. The wheat yield for each year was plotted with total rainfall during six months as shown in (Fig 3). It shows that increase in rainfall results in increase in wheat yield. The yield was 3440 kg ha^{-1} for rainfall 98.5mm, 6010 kg ha^{-1} for rainfall 209.5 mm and 5160 kg ha^{-1} for rainfall 182.6 mm respectively.

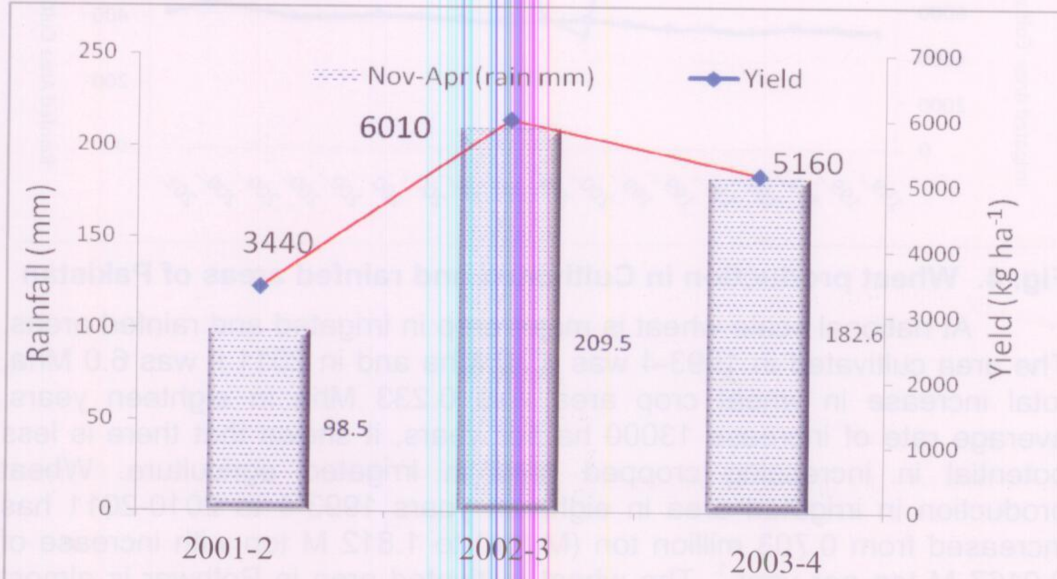


Fig 3. Six month rainfall and wheat yield in Chakwal 2001 to 2004.

Wheat Crop in Pakistan

Wheat grain has played a critically important role in meeting World nutritional needs in recent history, and is anticipated to continue doing so in the future. Pakistan is one of ten world's large wheat producing countries. Three marketing years (2007-08 to 2009-10), world top ten largest countries in terms of average World wheat harvested acreage were India (27.9 Mha), the European Union (25.4 Mha), Russia (28.7 Mha), China (24.0Mha), United States (20.2 Mha), Canada (9.5 Mha), Pakistan (9.04 Mha), Turkey (7.8Mha), Kazakhstan(14.7Mha) and rest of the world is (44.35Mha)http://en.wikipedia.org/wiki/Wheat.

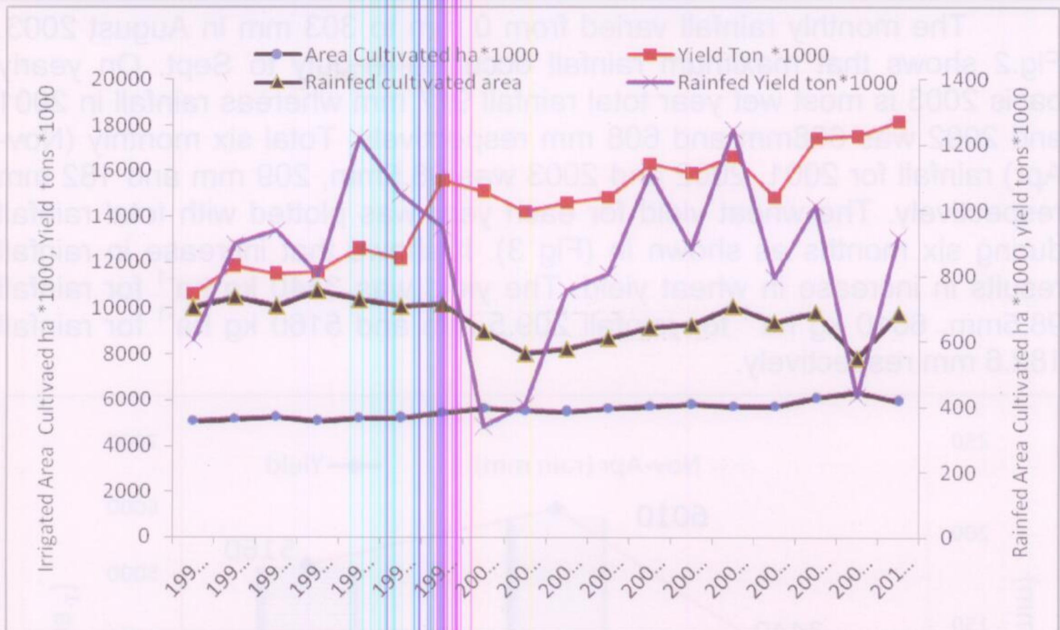


Fig. 4. Wheat production in Cultivated and rainfed areas of Pakistan

At national scale wheat is major crop in irrigated and rainfed areas. The area cultivated in 1993-4 was 5.76 Mha and in 2011 it was 6.0 Mha, total increase in wheat crop area was 0.233 Mha in eighteen years, average rate of increase 13000 ha per years, it shows that there is less potential in increasing cropped area in irrigated agriculture. Wheat production in irrigated area in eighteen years 1993-4 to 2010-2011 has increased from 0.703 million ton (M ton) to 1.812 M ton with increase of 0.0167 M ton per year^{-1}. The wheat cultivated area in Pothwar is almost the same in eighteen years from 1993-1994 to 2010-2011 whereas the yield variation is drastic in different years (Fig.4).

Wheat Crop in Pothwar

Wheat is grown over an area of about 8.2 Mha in Pakistan. In the Punjab province, the area under this crop is over 6 Mha out of which 10 percent is in rainfed. The national average yield of wheat crop is around 2.5 ton per hectare (t ha^{-1}) but average in rainfed areas is much lower and depends on the intensity, time and spread of rainfall. It ranges from 0.6 to 1.5 t ha^{-1} (Anonymous, 2004). The behavior of rainfall is highly variable but generally two third of it is received in the form of high intensity rainstorms during monsoon season from July to September. The wheat crop is sown in the months of October and November; therefore the success of this crop is directly related to the success in conservation of moisture received during monsoon months.

The rainfall plays an important role in crop production in Pothwar area. During year 2007 rainfall of 998 mm and in year 2009 rainfall of 850 mm was recorded. The rainfall pattern during year 2000 kharif was torrential whereas light showers were evenly distributed during 2001 season. Hence, the rainfall pattern during 2001 was environment friendly and created conducive conditions for crop growth. The growth and yields of the kharif crops during 2001 were therefore, better than the kharif 2000. Reporting similar results Lal and Ahmadi (2000) stated that when the seasonal rainfall varied, the difference in yields among the seasons also varied. The impact of rainfall on wheat production is shown in Fig.5. The cultivated area varies from 0.56 Mha to 0.7 Mha in different years from 1994-95 to 2010-11, whereas the yield varies a lot, minimum yield is 0.3 million ton for cultivated area of 0.63 Mha in year 2000-01, the annual rainfall was 500 mm. The maximum yield in year 1997-98 was 1.2 million tons for cultivated area 0.728 Mha, and rainfall was 1241 mm. It shoes that whenever amount of rainfall is increased the average yield is increased all the other inputs remain unchanged. Same pattern is shown for rest of the years. It is concluded that rainfall plays a major role for wheat production in Pothwar area of Punjab.

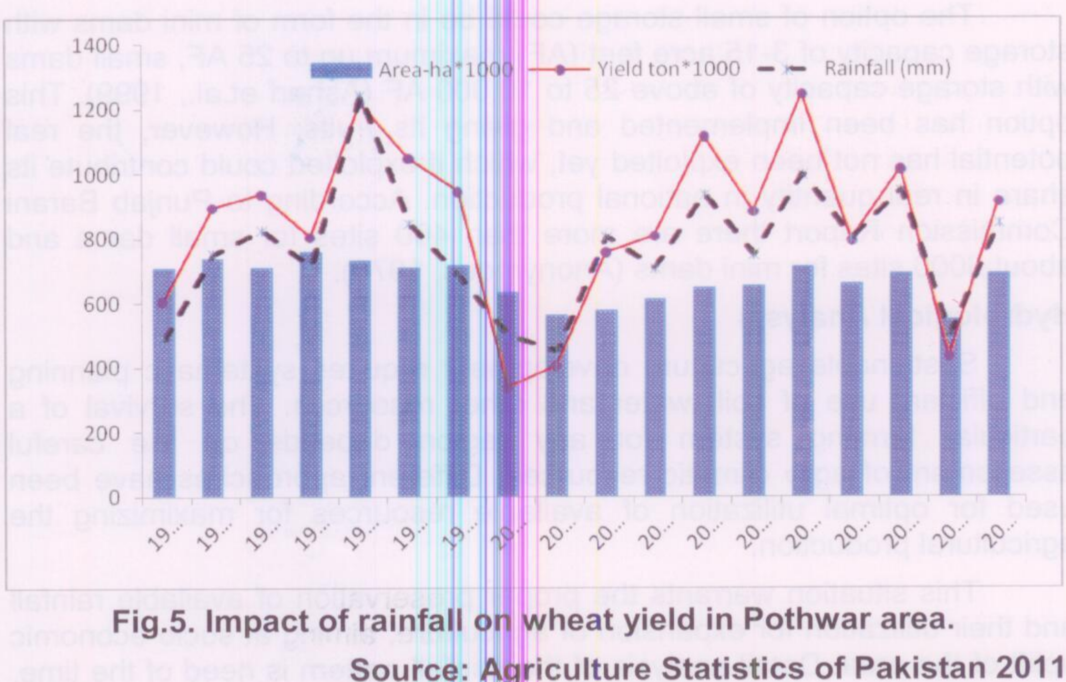


Fig.5. Impact of rainfall on wheat yield in Pothwar area.

Source: Agriculture Statistics of Pakistan 2011

Water Resources Conservation

The total amount of rainfall received in the Pothwar region is considered enough for crop production. However, temporal distribution and sequence does not match with crop demand. This deficiency can be overcome by water conservation, storage and rainwater harvesting techniques. Total run off water in Pothwar has been estimated at 3.5 MAF (Bhutta, 1999).

There are four major different ways of storing water viz. in the soil profile by deep plowing and allowing the rain water in infiltrate into soil. Sometimes different treatments such as gypsum and green manure are added to increase the soil moisture holding capacity of the soil. The groundwater recharge also increase the amount of water in underground aquifers, the leaky dams has been constructed in Baluchistan by Pakistan Council of Water Resources Research (PCRWR) in small reservoirs, and a large storage reservoirs behind large dams. Storage in the soil profile is extremely important for crop production, but it is relatively short-term storage. Small reservoirs have the advantage of being operationally efficient. They are flexible, close to the point of use and require relatively few parties for management. The options of large reservoirs are difficult to implement due to financial and social constraints. The only viable option in Pothwar Plateau is small storage.

The option of small storage could be in the form of mini dams with storage capacity of 3-15 acre feet (AF) maximum up to 25 AF, small dams with storage capacity of above 25 to 10,000 AF (Asharf et.al., 1999). This option has been implemented and giving its fruits. However, the real potential has not been exploited yet, which if exploited could contribute its share in real quantity in national production. According to Punjab Barani Commission Report there are more than 400 sites for small dams and about 8000 sites for mini dams (Anonymous, 1976).

Hydrological Analysis

Sustainable agriculture development requires systematic planning and efficient use of soil, water and other resources. The survival of a particular farming system for any region depends on the careful assessment of agro climatic resources. Different approaches have been used for optimal utilization of available resources for maximizing the agricultural production.

This situation warrants the proper preservation of available rainfall and their utilization for expansion of agriculture, aiming at socio-economic uplift of the area. Detail analysis of the rainfall pattern is need of the time.

The sound prediction of rainfall can help the farmers to plan the sowing and harvesting time of crops. It requires enormous and systematic hydrological, topographical and climatic data. Statistical and stochastic tools are used for the historical data analysis and prediction of rainfall-runoff pattern at large scale during the year.

Hydrological was analyzed to assess the rainfall pattern in Pothwar area, the probability analysis was also carried out to estimate how much rain is available at different time scale.

The annual rainfall in Pothwar area is shown in Fig 1.

Rainfall distribution analysis is used to identify the trend of rainfall through the year and change in rain fall pattern in the study area both at temporal and spatial scales. Historical Analysis of rainfall of Chakwal was done on temporal scale (Fig 6).

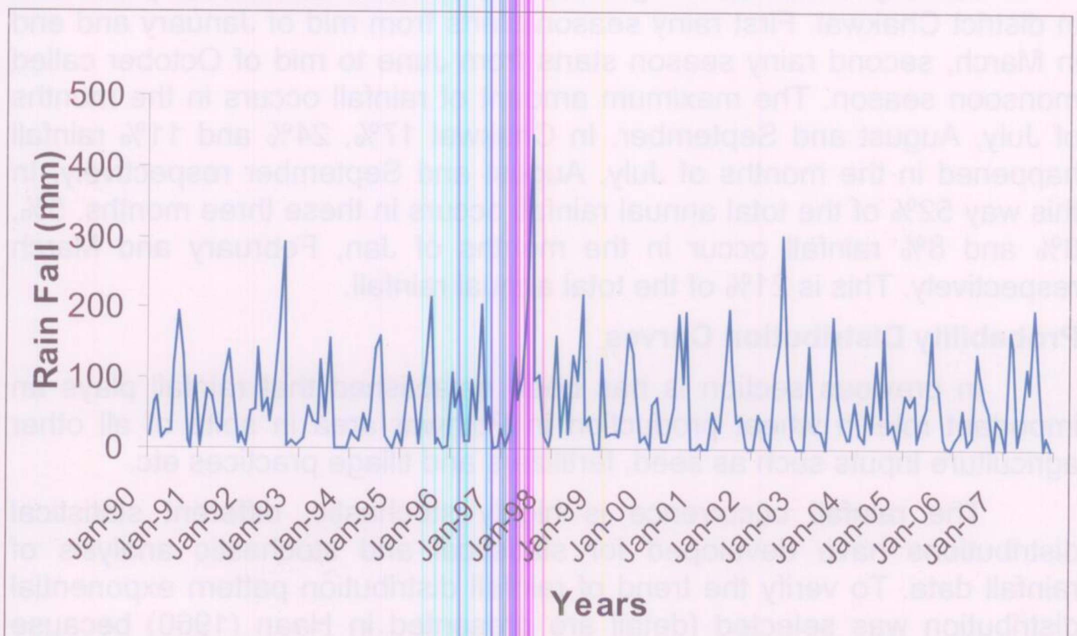
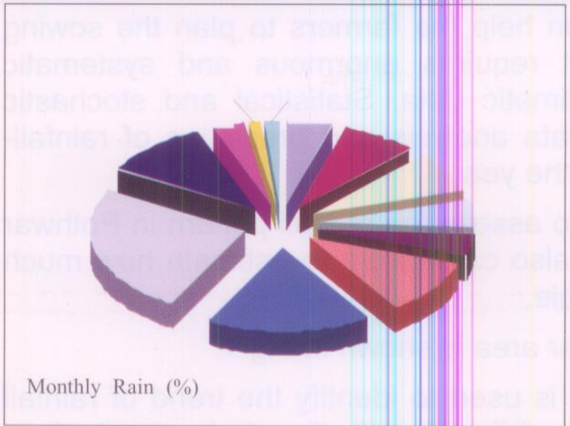


Fig. 6. Rain fall distributions of Chakwal.

Fig. 6 is representing the historical behavior of rainfall trend of Chakwal in ten years. This shows that after 4 to 5 years a peak of rainfall comes and then the rainfall pattern goes to normal condition. The maximum rainfall has occurred in 1998 within the study data.



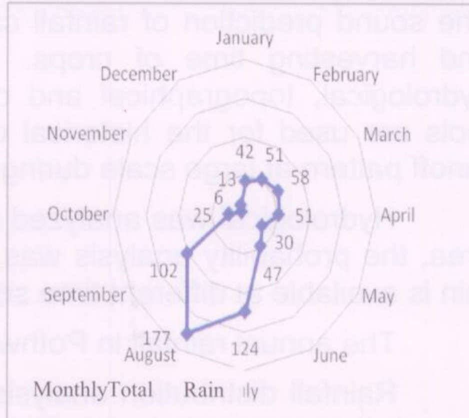


Fig. 7. Average monthly rainfall distribution pattern of Chakwal.

Monthly rainfall data Fig.7 shows that there are two rainy seasons in district Chakwal. First rainy season starts from mid of January and end in March, second rainy season starts from June to mid of October called monsoon season. The maximum amount of rainfall occurs in the months of July, August and September. In Chakwal 17%, 24% and 11% rainfall happened in the months of July, August and September respectively. In this way 52% of the total annual rainfall occurs in these three months. 5%, 8% and 8% rainfall occur in the months of Jan, February and March respectively. This is 21% of the total annual rainfall.

Probability Distribution Curves

In previous section is has been established that rainfall plays an important role in wheat production in Pothwar area in spite of all other agriculture inputs such as seed, fertilizers and tillage practices etc.

The rainfall occurrence is highly stochastic, different statistical distributions have developed for statistical and stochastic analysis of rainfall data. To verify the trend of rainfall distribution pattern exponential distribution was selected (detail are presented in Haan (1960) because frequency distribution of the Pothwar region is also making the exponential distribution curve pattern. The rainfall distribution pattern of Chakwal is shown in Fig 8.

The purpose of probability analysis was to adjust the sowing time of wheat crop accruing to maximum probability of rainfall occurrence in sowing months i.e., November, December. For this probability analysis of rainfall occurrence on weekly basis was done for district Chakwal shown in Fig.8.

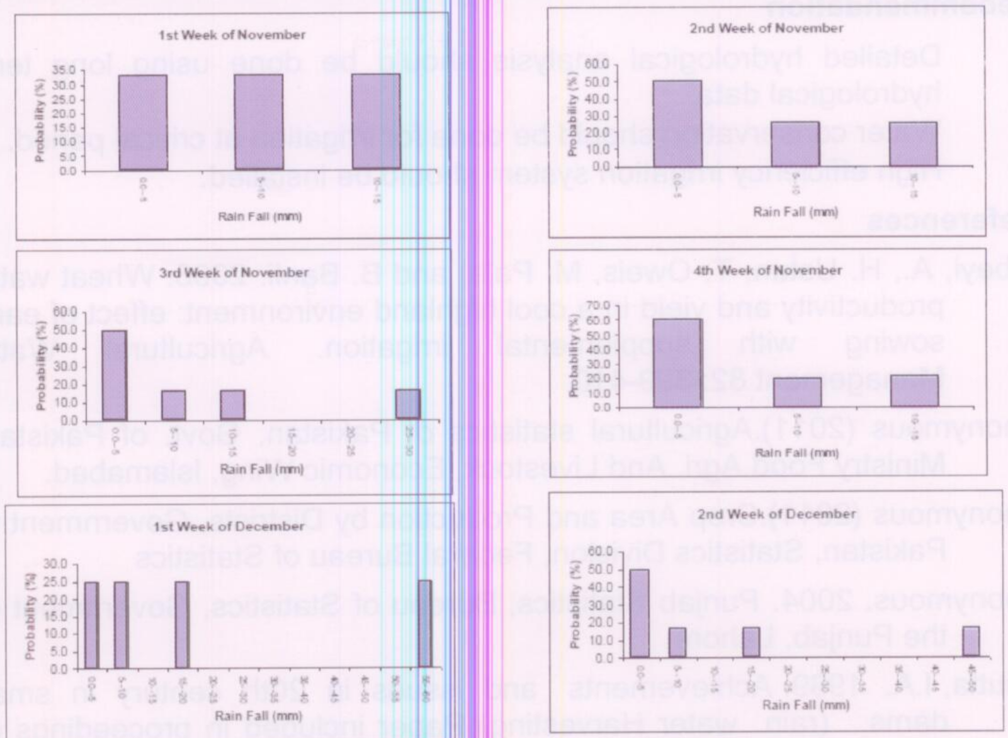


Fig. 8. Probability plot on weekly basis for district Chakwal

The 1st week of November has 35% probability for rainfall occurrence 10mm to 15 mm, whereas in 2nd and 3rd week probability is 50% for 5mm rainfall. In most of the hydrological analysis 5mm rainfall is assumed as insignificant to produce runoff, but in case of soil moisture this amount is important. In case of 1st week of December there is equal probability of rainfall up 50 mm to 60 mm which is significant amount and in 2nd week of December 50% probability to receive rainfall of 5mm. It is concluded if wheat crop is sown in 1st week of November and 1st and 2nd week of December, there is maximum chance of rainfall, that will be helpful in good seed germination and crop stand.

Conclusions

- Rainfall is basic parameter for crop production in Pothwar region.
- Soil moisture conservation using tillage practice and gypsum input increase the crop production.
- The crop calendar should be changed according to rainfall availability, the 1st and 2nd week of November and 1st week of December seems to be more optimal for sowing of wheat crop.

Recommendation

- Detailed hydrological analysis should be done using long term hydrological data.
- Water conservation should be done for irrigation at critical period.
- High efficiency irrigation system should be installed.

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Impact of Water Resources Management on Agriculture and Environment with Dungi Dam in Pothwar Area

By

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Engr. Muhammad Mumtaz[3]

ABSTRACT

Management of water resources in the arid regions of Pothwar is imperative for profitable agriculture and to keep the environment friendly. Government of the Punjab has constructed 31 small dams in the Pothwar region to store and conserve water for agriculture production and domestic use. The effective utilization of these dams can bring green revolution in the area. The reservoirs of these dams, however, are subject to huge evaporation losses. The estimated loss of water due to evaporation is 1.74 m/year which is about 20% of the storage capacity of these dams. The storage capacity of these dams has, however, reduced by about 25% due to silt deposition and vegetative growth.

A study was conducted to document the impact of Dungi Dam on Agriculture, groundwater, environment and their positive effect on the socio-economic conditions of the farmers. It was observed from the data that dam has increased the cropping intensity from 120% to 200% and yield of crops also increased from 150% to 167% and with the recharge to groundwater water table rises and become easy to farmers for drinking purpose. The installation of dug wells has increased many folds after the construction of the dam. The land use and crop intensities and crop yield have also increased many folds.

Transformation of cropping pattern from traditional to high value crops has taken place. An analysis of inflow-outflow from the reservoirs shows that releases are meeting the designed water requirements resulting increase in cropping intensity as the planned value. However, if

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properly managed, more area could be irrigated with existing facilities and available water resources. This study also proposes strategies for efficient management of available water resources. The main conclusion of this study in this project is environment friendly.

KEYWORDS: Dungi Dam, Pothwar, Groundwater, Water resources management, Cropping intensity, Land use intensity and Crop yield.

INTRODUCTION

Pakistan's economy depends on agriculture which contributes 21% of Gross Domestic Product (GDP). Apart from producing food, it provides raw material for agro-based industry. Out of about 22.16 million hectares (Mha) of Country's total culturable land, 17 Mha are irrigated with a culturable waste of about 9.30 Mha (MINFAL, 2011-12). The Pothwar Plateau spreads over 2.2 Mha and has great potential for agricultural and social development. Total cultivated area of Pothwar Plateau is around 1.0 Mha. The occurrence of rainfall in barani areas is highly erratic both in space and time. The average annual rainfall ranges from 1000 mm in the Northeast to 350 mm in the Southwest and about 70% rainfall occurs during the monsoon season (Ashraf *et al.*, 1999). Two major streams, Soan and Haro, carrying much of the areal runoff pass through the region and finally joins the Indus River however, Kanshi River transverses the region. The total runoff potential of about 3.50 million acre foot (MAF) passes the Pothwar Plateau which is not generally available for agriculture (Bhutta, 1999). Moreover, due to the uncertainty of rainfall, farmers normally minimize inputs to reduce the risk of loss in the event of drought and mainly depend on off-farm incomes for their sustenance. Agriculture in this area is just at subsistence level, primarily due to acute shortage of assured irrigation supplies. Other factors contributing to meager agriculture in the area include fragmentation, obsolete methods of farming, lack of institutional and infrastructure facilities. The present average land holding is generally less than few acres. The trend of division of land holdings and migration has disrupted the social balance in the Pothwar Plateau and is hindering further economic development. The Government of Punjab through Small Dams Organization (SDO) has constructed 31 small dams in Pothwar plateau since 1961. These dams are designed to irrigate over 35000 acres. However, NESPAK (1991) has concluded that only 32% of the anticipated command area has been developed. On an average, 69% water is being released from these reservoirs. Bhutta (1999) reported that only 42% of command area has been developed. Shah (1984) evaluated small dams in Punjab and found that due to the availability of water, the crop yield has been increased 36% in case of wheat and 51% in case of maize. Iqbal and Iqbal, M.S., S.A. Shahid (1992). concluded that less than one third of the proposed area was being irrigated by small dams. Therefore, the desired changes in cropping pattern could not be accomplished. Due to high surface area to volume ratio, these small reservoirs are subject to high evaporation losses. On an average, small reservoirs loss 50% of their impoundments to evaporation in arid and semi-arid areas (Sakthivadivel *et al.*, 1997). The seepage and percolation losses in small reservoirs are about 20% of reservoir volume against 5% in large dams (Keller *et al.*, 2000). The unit cost of small dams is also relatively high. The cost per acre-feet (AF) of water is from Rs. 62 to Rs. 1975 for large reservoirs whereas it is from Rs. 430 to Rs. 6800 for medium and small dams (Keller *et al.*, 2000). The small dams in Pothwar are also subject to high evaporation losses. With an average evaporation rate of 1.74 m/year, these reservoirs waste about 20,000 acre-feet (AF) of water annually (NESPAK, 1991). Since the evaporation losses and unit cost of water stored in small dams are relatively high, therefore, it becomes imperative that the stored water should be used judiciously and efficiently. It has been shown that the potential of small dams has not been fully explored and they are being under utilized. There is, however, need to identify the underlying limitations of low land and water productivity to suggest possible strategies to enhance the crop production.

To study and document: (i) the impact of small dam on groundwater, (ii) change in cropping intensity, (iii) increase in crop yield and (iv) suggest possible strategies for improving land and water productivity, Dungi dam was selected in the Pothwar area near Gujjar Khan Tehsil of Rawalpindi District.

Location of Dungi Dam

Dungi dam is located at about 7.0 km North West of Gujjar Khan town, District Rawalpindi having total catchment area of 19.9 sq. Km.The dam site is on Huchiara kas, a tributary of Kanshi river which ultimately outfalls into Jhelum River as shown in Figure 1 and hydrology of Dungi Dam is given Table 1.

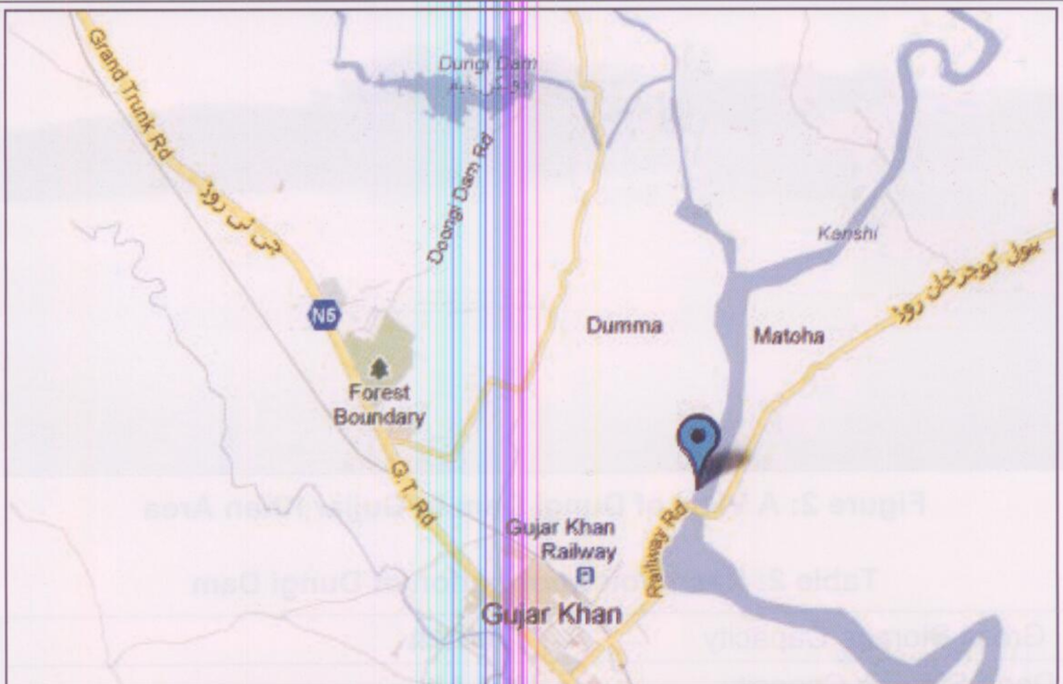

Figure 1: Location Map of Dungi Dam in Gujjar Khan Area

Table 1: Hydrology of Dungi Dam

Area of catchments up to dam site	7.7 Miles 2 = (19.9 Sq. Km)
Annual Rainfall	30.82 Inches (783 MM)
Average Annual Sedimentation	8 Aft/ Sq. Miles
Maximum Routed Discharge	1195.3 Cusecs (33.9 CMS)

Some basic information of Dungi Dam is given in Tables 2 to 5 and the pictorial view of different components of Dungi Dam are shown in Figures 2 to 7.

Figure 2: A View of Dungi Dam in Gujjar Khan Area

Table 2: Reservoir Information of Dungi Dam

Gross Storage Capacity	1760 Aft
Dead Storage Capacity	801 Aft
Live Storage Capacity	959 Aft
Normal Resevoir Level	1502.50 Ft (458.08 M)
Dead Storage Level	1490 Ft (454.27 M)
Pond Area at Normal Water Level	102 Acres (41.30 Ha)

Figure 3: An-other View of Dungi Dam in Gujjar Khan Area

Table 3: Design Data of Dungi Dam

Type	Concrete Dam with Earthen Flanks
Maximum Height	71.40 ft (21.77 m)
Length at Top	952 ft (290.24 m)
Top Width	20 ft (6.10 m)
Top Level of Dam	1511 ft (460.67 m)

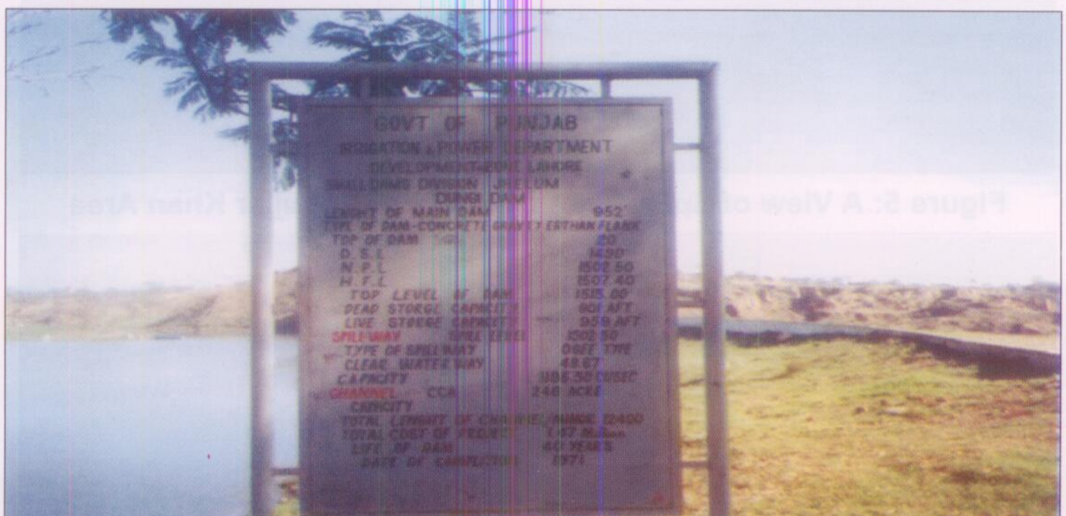

Figure 4: A View of Basic Information Displayed on Board at Dungi Dam in Gujjar Khan Area

Table 4: Design Data of Spillway (Dungi Dam)

Type	Un-gated Chute Spillway
Spill Level	1502.50 (458.08 m)
Clear Water Way	58.67 ft (17.89 m)
Capacity	1195.30 Cusecs (33.88 CMS)
Total Cost of the Dungi Dam	Rs. 1.47 Million
Completion Year	1971
Year of Construction	1971

Figure 5: A View of Spillway of Dungi Dam in Gujjar Khan Area

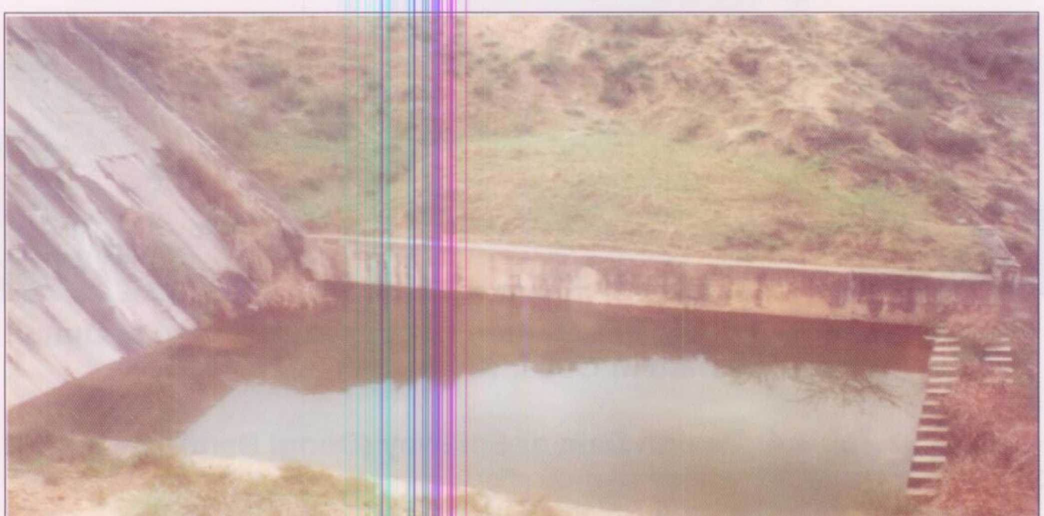

Figure 6: A View of Plunge Pool of Dungi Dam in Gujjar Khan Area

Table 5: Irrigation System on Dungi Dam

Type of Irrigation	Surface (Gravity Flow)
Cultivable Command Area (CCA)	246 Acres (99.6 ha)
Cropping Intensity on an Average	120
Kharif	65%
Rabi	55%

Capacity of System	5.4 Cusecs
Type of Lining	Cement Concrete
Slope of Main Canal	1:2000
Length of Main Channel/Minor	11400 ft (3475.61 m)

Figure 7: A View of Irrigation Channel Regulator of Dungi Dam in Gujjar Khan Area Beneficiaries Villages

METHODOLOGY

Selection of Dungi Dam and Data Collection

One small dam namely Dungi Dam, situated in Gujjar Khan near Rawalpindi division, was selected for the study. This dam was constructed by Small Dams Organization Punjab, in 1971 mainly for irrigation purposes. Data such as inflow and outflow of water, *aabiana* (water charges) and other related information for these dams were collected from Small Dams Organization, Punjab. Data regarding depth to water table in the command of Dungi Dam was collected from the field.

Data Collection and Analysis

All the primary and secondary data collected were analyzed to identify the impacts of Dungi Dam on the groundwater, agriculture development in terms of land use intensity, cropping pattern, irrigation practices, crop yield, and consequently on the socio-economic uplift of the area.

RESULTS AND DISCUSSION

Rainfall in the Command of Dungi Dam

Rainfall data is also collected by the representative of Small Dam Organization at Dungi Dam. The collected data was analyzed and it was noted that on an average 250 mm rainfall contributes annually in the inflow of Dungi Dam. The Figure 8 shows the rainfall in different years and Table 6 shows the average annual rainfall.

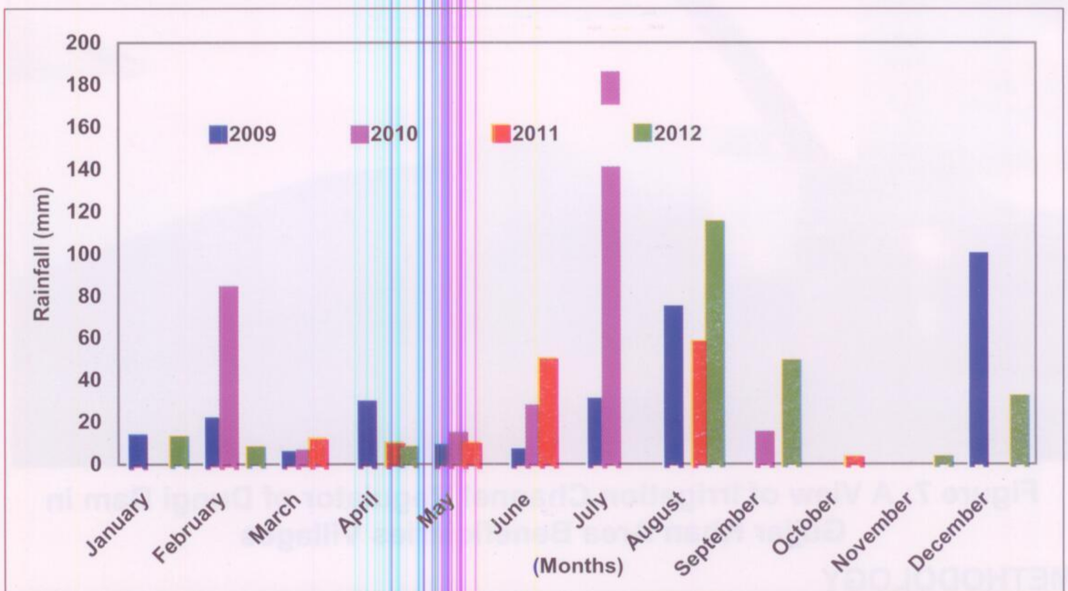

Figure 8: Rainfall during Different years in the Command of Dungi Dam in Gujjar Khan Area

Watertable Depth in the Command of Dungi Dam

Watertable depth from natural surface level (NSL) was measured in the month of March, 2013. It was observed that watertable is near to ground surface. The depth of watertable ranges from 1 to 12 m depth. This huge variation in watertable depth is due to uneven topography in the command of Dungi Dam. It is worth to note that prior to Dungi Dam, the watertable depth was more than 30 m. Now with the construction of Dungi Dam watertable came up and facilitated the inhabitants of the area to punp water for drinking purpose easily. The Figures 9 & 10 show the watertable measurements from the open wells in command of Dungi Dam. The Figure 11 shows the watertable depth in different open wells during March, 2013 in the command of Dungi Dam.

Figure 9: A View of Depth to Watertable Measurement from Open Well in Command of Dungi Dam

Figure 10: An-other View of Depth to Watertable Measurement from Open Well in Command of Dungi Dam

Figure 11: Watertable Depth from NSL in Dungi Dam Command-Gujjar Khan Area during March-2013

Inflow-Outflow Analysis of the Dams

Dungi Dam

The dam was designed to irrigate 246 acres of land. The inflow-outflow data of the dam showed that the inflow is less as compared as with the outflow. Maximum inflow was obtained during July-August and maximum releases were also obtained during these months. There was no inflow during November-December. During May and June, outflow was greater than inflow. This was due to hot weather conditions and lack of rainfall during these months. Total average annual inflow is 470 aft, whereas, average annual outflow is 633 aft. However, if releases are made according to inflow in the dam, more area can be brought under cultivation and cropping intensity can be increased. Table 6 and Figures 12, 13, 14 and 15 show the average yearly water availability, inflow, discharge (out-flow), and evaporation respectively of Dungi Dam.

Table 6: Average Annual Rainfall, Water Availability and Inflow-Outflow during Different Years in the Command of Dungi Dam

Years	Rainfall (mm)	W. Availability (aft)	Inflow (aft)	Evaporation (aft)	Discharge (aft)
2012	228	735	567.63	21.33	329.52
2011	143	966	116.64	21.53	828.71

2010	336	876	724.16	55.515	619.15
2009	294	912	471.6	41.02	756.06
Annual Avg.	**250**	**872**	**470**	**35**	**633**

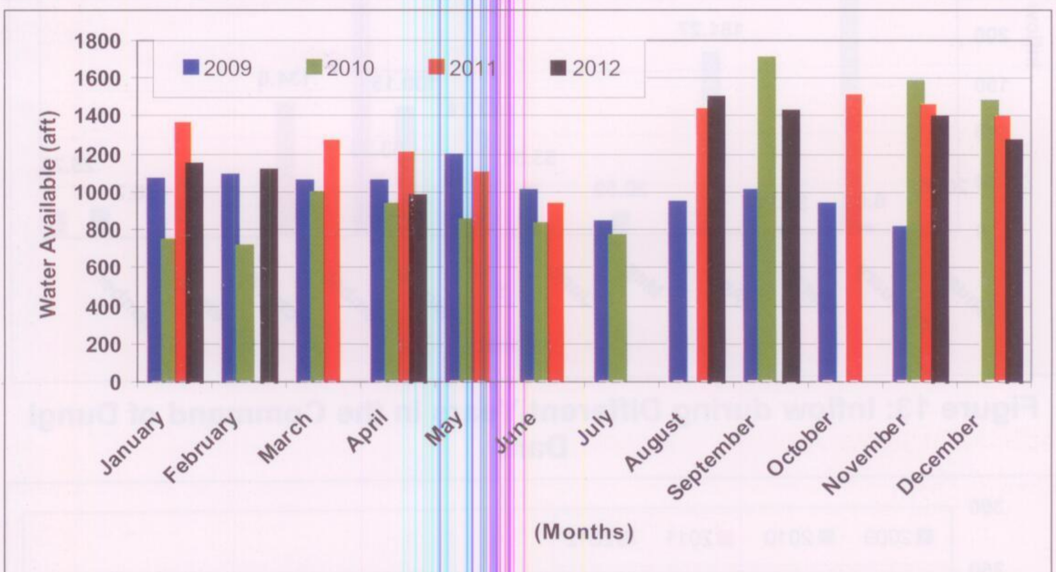

Figure 12: Water Availability during Different Years in the Command of Dungi Dam

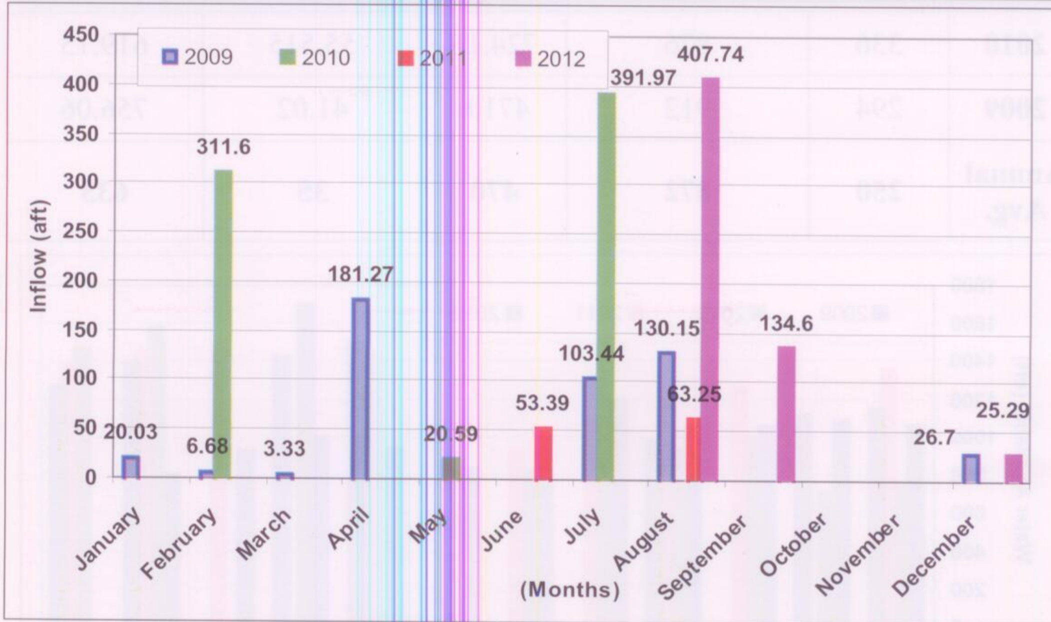

Figure 13: Inflow during Different Years in the Command of Dungi Dam

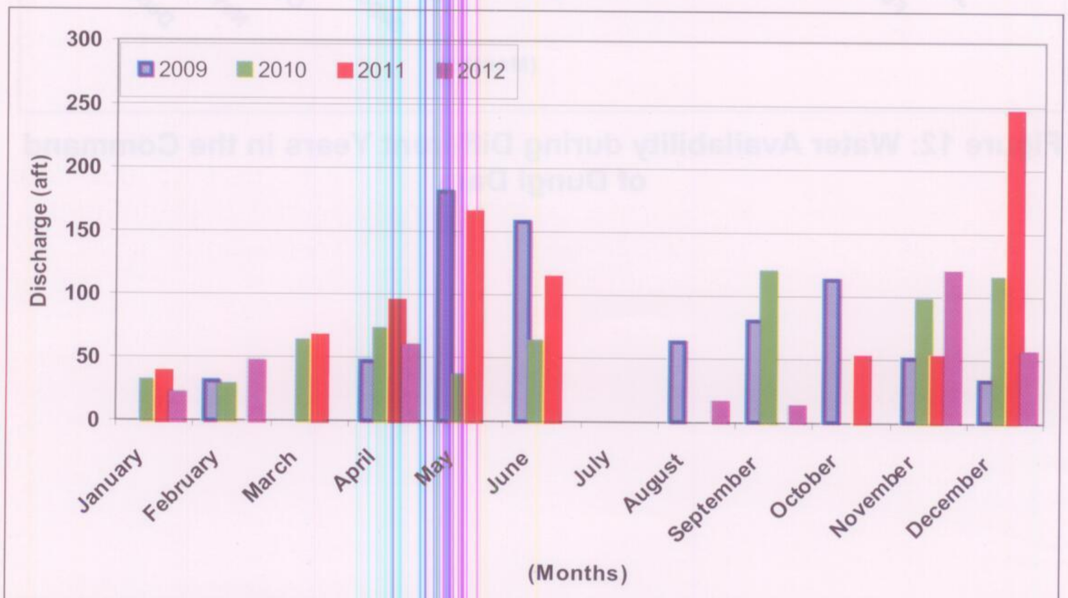

Figure 14: Discharge during Different Years from the Stored Water of Dungi Dam.

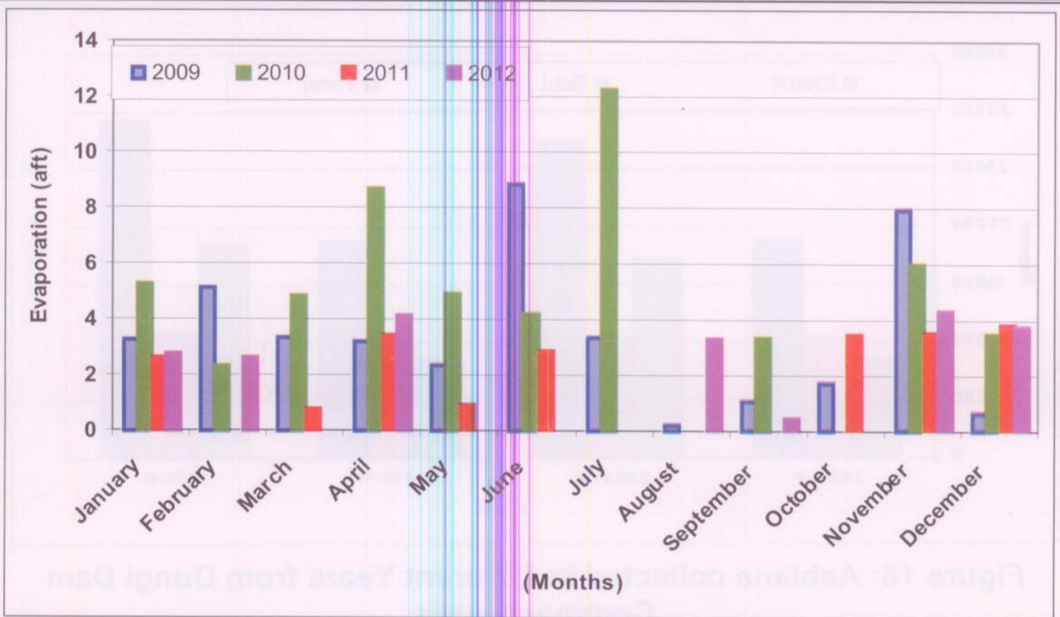

Figure 15: Evaporation Losses during Different Years from the Dungi Dam Surface Area

Contribution of Small Dams in the Development of Water Resources of the Pothwar

Water Rates (*Aabiana*)

Aabiana is the water charges paid by the farmers to the dam authorities. Figure 16 shows water rates charged by the dam authorities per year. It reflects that water charges per year (revenue collected) increased gradually. This was mainly due to increase in area under irrigation with time as well as yearly increase in *aabiana* (water rates). However, it is worth mentioning that the selected dam achieve the designed income from water rates.

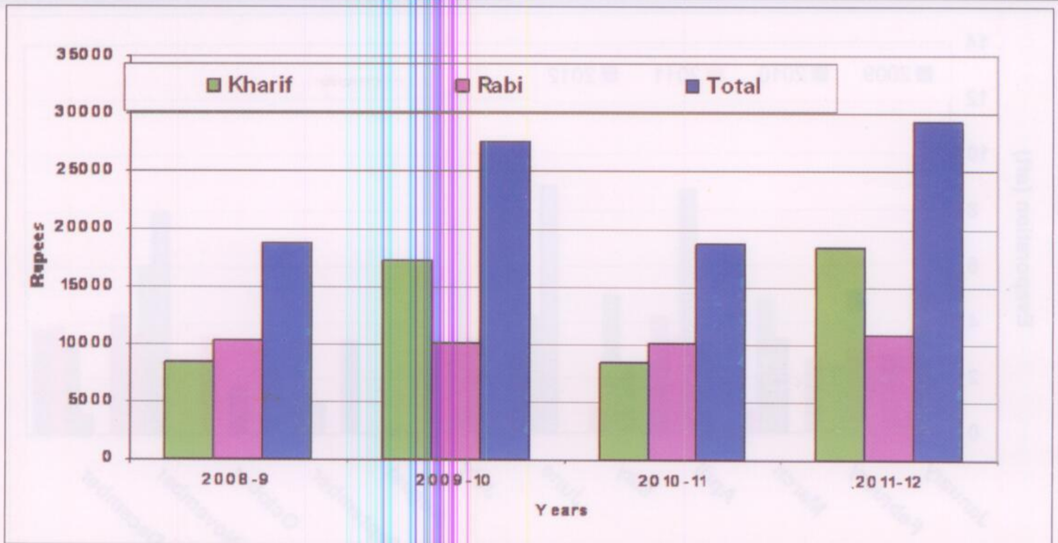

Figure 16: Aabiana collected in Different Years from Dungi Dam Command Area

Land and Water Management Practices

Land Holdings

Majority of the farmers of the project area are holding land only few acres. Only few farmers are holding land greater than 10 acres. The average land holding ranges from 2.5 to 21.5 acres in the surveyed area

Land Use and Cropping Intensities

Generally the command areas consist of terraces. The land is very fertile and has high potential for agricultural development. Before the construction of the dam, the area was totally dependent on rainfall. Wheat and fodders were the major crops at that time and the cropping intensity was upto 65-70%. After the construction of the dam, the cropping intensity as well as cropping pattern has totally changed. Significant increase in cropping intensity i.e. 199 to 200% and land use intensity has also been increased in the command of Dungi Dam as shown in Figure 17.

Figure 17: Cropping Intensity in the Command of Dungi Dam in Gujjar Khan Area

Surface and Groundwater Resources

Before the construction of dams, the agriculture was mostly dependent on rainfall and partly on open wells. After the construction of dams, a significant change has been observed and about 100% water for crop is being obtained from the dam through irrigation channel in the mode of surface irrigation.

Groundwater Development

Besides supplying water for irrigation, dams have many indirect benefits. They help recharge the groundwater, provide water for domestic and municipal purposes, control erosion, control floods in hilly and plain tracts, help develop fish culture and also provide recreational activities (Ashraf *et al*., 2000). Prior to the construction of dams, the water-table depth was too deep and the farmers were unable to irrigate their lands from the wells, due to acute shortage of water in the area. Majority of the people migrated from this area due to the scarcity of water. The number of deep wells and dugwells could be counted on fingertips before dam construction and now the open well exists in each house. At present, the water table varies from 3-12 m and 7-39 m from the ground surface near to the dam area, which was at 10-25 m before the construction of dam.

Irrigation Methods

Before the construction of dams, the farmers were generally practicing flood irrigation. Farmers are now moving from flood irrigation to high efficiency surface irrigation, such as furrow irrigation, which is now commonly practiced in the area. However, the pressurized irrigation system, the most efficient one is not installed by any farmer. The reasons are the regular supply of water from dam, high capital cost of the system, and farmers' lack of knowledge about the system. In the command of Dungi Dam some farmers are still using Persian wheel for irrigation their crops as shown in Figures 18 & 19.

Figure 18: A View of Persian Wheel being used in the Command of Dungi Dam in Gujjar Khan Area

Figure 19: An-other View of Persian Wheel Being used in the Command of Dungi Dam in Gujjar Khan Area

Cropping Pattern

Before the construction of these dams, the people of the area were totally dependent on rainwater. Wheat was the only major crop however; vegetables, maize, bajra and fodder were grown only on very limited scale, mainly for farmers' own use. After the construction of small dams, there is a shift of cropping pattern from low valued crops towards high valued crops (Table 7). Wheat being the staple food crop is grown on almost all farms during *Rabi* season. Mostly people grow wheat for their domestic use. Further, vegetables are now grown as major cash crop at the dam besides maize. Even some people are growing early season vegetables and earning good money. Being vegetables and wheat as cash crops, the economic status of the area is better as compared to other areas of the same locality.

Crop Yields

Before the construction of dam, the crop yields were relatively low. With the development of dam in the studied area, significant increase in the yield of crops has been observed (Table 7). In the area different vegetables and cereal crops are cultivated in different seasons. It shows that about 1200 kg of wheat from an average field of one acre is obtained which was about 600 kg prior to the construction of dam. The people of the area especially in the command of Dungi Dam are very happy and prosper. Healthy wheat crop in field is shown in Figures 20, 21 & 22.

Table 7: Cropping Pattern and Crop Yield (Pre and Post Dungi Dam)

Crop	Pre-DamYield (Kg/acre)	Post-Dam Yield (Kg/acre)	Yield Increased (%)
Wheat	600-800	1200-1400	75-100
Maize	400-600	600-800	33-50
Bajra	320-400	500-700	56-75
Jawar	400-600	700-800	33-57
Rabi Fodders	300-400 (Maunds)	600-700 (Maunds)	75-100
Kharif Fodders	150-200 (Maunds)	400-500 (Maunds)	150-167
Vegetables	Domestic Use	Domestic and Marketing	Marketing

Income of Farmers

Farmers of the Dungi Dam were interviewed and it was noted that with the construction of dam, the income of farmers has increased, due more area is being cultivated with growing high valued crops. In *Kharif* season, the average income ranges from Rs. 20,000 to 25,000 and in *Rabi* it is Rs. 25,000- 35,000.

Benefits with the Dungi Dam

The rainfall is the only source which contributes the Dungi Dam through Kanshi River Catchment, which made the development of Barani agriculture. The extreme variation in annual rainfall (about 70% in monsoon *i.e.* July to September) and all rainfall in the Dungi Dam Catchment is easily stored in the dam and rainfall runoff is managed and protection to fertile soil/land from scouring, which is the main benefit to the inhabitants. The other major benefits of the area are plentiful of water for drinking and domestic purposes are available and every farmer has his own open well in his house. The Main beneficiaries from Dungi Dam are the following three villages.

1. Dungi Village, 2. Dumma Village and
3. Dhorey

Other Benefits with the Construction of Dungi Dam

1. Social: Water Supply to Small Industries Estate Gujjar Khan

2. Infrastructure Development

3. Economical Benefits: Poverty Alleviation (Growing Different types of Crops)

4. Environmental Impact: i) Green Revolution, ii) Fisheries

5. Institutional Impact: i) Extension Services,

ii) Soil Conservation (Command Area Development)

Figure 20: A View of Wheat Crop in the Command of Dungi Dam in Gujjar Khan Area

Figure 21: An-other View of Wheat Crop in the Command of Dungi Dam in Gujjar Khan Area

Figure 22: An-other View of Wheat Crop in the Command of Dungi Dam in Gujjar Khan Area

Water Diversions

The water diversion to the watercourses from the irrigation channel which is off-taking from the Dungi Dam is very regular and they turn water with their own turn. The farmers at the tail reach are also receiving sufficient water for their farms. As the command area of Dungi Dam is not so larger, therefore, farmers are arranging their irrigation water turn very easily.

Maintenance of Watercourses in the Command of Dungi Dam

The watercourses in the command of Dungi Dam areas are not too lengthy and it is very easy to look after the watercourses throughout the season by the farmers. The entire watercourses are properly maintained. The watercourses are being cleaned regularly on annual basis.

Undulated Fields

Farmers normally try to level their fields conventionally with tractor and scraper. However, precision leveling is far away. Due to undulated fields, huge amount of water is wasted. There is need to level these fields precisely, so that the limited water could be used with efficient manner. The On Farm Water Management along with Agricultural Extension services could help level the fields and increase water productivity.

Lack of Agricultural Support Services

Agricultural extension services play a pivotal role in the motivation of farmers towards the adaptation of improved irrigation and cultural practices, introduction of high valued crops, efficient use of water and proper use of non-water inputs. However, it was observed that extension services were hardly available at any dam. Similarly, On Farm Water Management (OFWM) activities were rarely seen in these areas. It is suggested that a well coordinated and integrated approach by OFWM and Agriculture Extension Department should be adopted to get maximum benefits from the available water resources. This would ultimately improve the socio-economic conditions of the area.

KEY FACTORS FOR THE MANAGEMENT OF WATER RESOURCES

Land Leveling and Proper Farm Layout

The layout of most of the fields is based on traditional flood basin comprising a number of unwanted dikes and ditches. Due to undulated fields, the application efficiency is very low resulting in huge loss of water. The fields should be properly leveled and the farm layout should be properly designed based on the soil type and discharge available. Precision Land Leveling (PLL) is a topographic modification of land and involves grading and smoothing of land to an even level, with little or no slope. PLL improves irrigation application efficiency and increases the uniformity of water application with less chance of over and under irrigation. It has been reported that this technology can increase the land use intensity from 8%-63% and cropping intensity from 6%-70% (Gill, 1994). Therefore, leveled fields are not only help reduce the amount of irrigation water required but also help to reduce the labour requirements. On Farm Water Management (OFWM) and Water Users Approach (WUA) could play an important role in the leveling of fields.

Adoption of High Efficiency Irrigation System

Basin irrigation is the commonly used method in Pakistan. However, application efficiency of this method is very low. Surface irrigation techniques can be improved by developing crop specific field layouts. Efficient surface irrigation methods such as bed and furrow irrigation system help save water. In the bed and furrow method, water is applied only in furrows. With the passage of time, the furrow beds become relatively hard due to silt deposition. Water then moves laterally and vertical seepage of the water reduces considerably. Since water is applied in furrows, the effect of water born and water transmitted diseases on the crop health is minimal. Due to the scarcity of water, merely 25% of total rain-fed areas are under cultivation. The farmers use obsolete methods of irrigation resulting in poor application and distribution efficiencies. In most of the areas, the land is highly undulated; therefore, precision land leveling is not feasible option. Under the prevalent topographic conditions, gravity irrigation is also not possible.

Therefore, it is of utmost importance that the scarce water resources in the region are utilized most aptly and efficiently with minimum losses. Highly efficient sprinkler and trickle irrigation techniques have been successfully introduced in Pakistan, and are particularly well suited to the water scarce barani areas. Application efficiencies of these systems can be very high (75 to 85%), thus permitting almost full use of the scarce water supplies. An additional advantage as compared with other methods of surface irrigation is that efficient irrigation can be carried out even, where, topography is undulated and soil is of light texture, as is the case in much of the barani areas.

Proper Irrigation Scheduling

Agriculture is the major consumer of water in Pakistan. However, water application and water use efficiencies are very low. The main reason for low efficiency is the over irrigation by the farmers. Farmers normally over irrigate the field due to: (i) lack of proper knowledge about irrigation scheduling; and (ii) with the intention that more water will produce more yield. However, more applications of water may result in low water use efficiency and low net income. Moreover, over irrigation leaches the nutrients out of the root zone and decreases the crop yield (Ashraf *et al.*, 2001). Though the year 1999-2002 was a drought year with low river flows and less amount of irrigation water availability, yet about 2.0 million tons of surplus wheat was produced. The high yield of wheat indicates that this could have been the result of greater use of groundwater over which the farmers had relatively better control. The farmers were able to apply the right amount of irrigation at the right time, thus avoiding over irrigation. Proper irrigation scheduling helps farmers to know when to irrigate and how much to apply? This issue is mostly related to awareness and education of the farmers.

Impact of Dungi Dam on Environment

It is fact that Dungi Dam has the positive impact on environment. Due to the Dungi Dam hundreds of trees are grown by the farmers in their land and also in their homes. Crops are being grown every where. Green revolution came in the area due to the construction of the dam. In the dam area greenery could be seen, people are healthy and prosperous, due pollution free environment.

CONCLUSION AND RECOMMENDATIONS

The studied dam has been partially successful to improve the socio-economic conditions of the local inhabitants. Groundwater (mainly due to recharge from dam) has become easily accessible for pumping due to which number of dug-wells has increased many folds after the construction of the dam. This reduced drudgery on the local inhabitants particularly women who have to fetch water from far away for their domestic uses. The land use and crop intensities, crop yield have also increased many folds after the construction of the dam. There is a shift of cropping pattern from the traditional cropping towards high valued crops due to the availability of water. The designed command area at dam has not been fully developed so far. The analysis of the dam inflow-outflow shows that average annual water released is adequate to achieve the designed crop intensity. However, if properly managed, more area could be irrigated with the same infrastructure/existing facilities and with the same water availability. There are several bottlenecks in the full utilization of these dams such as: (i) poorly maintained field channels; (ii) undulated fields; and (iii) lack of agricultural support services *etc.* Well coordinated efforts are required to overcome these issues. An integrated programme should be formulated and implemented in command areas for effective utilization of available water as well as developed infrastructure. In this regard, a pilot programme would be helpful to optimize the implementation process as well as operation and maintenance of efficient land and water management activities in command area of developed Dungi Dam.

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