Farm Mechanization Options Under Climate Change Scenarios in Pakistan

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1. Introduction

Pakistan is situated between 241˚ and 371˚ N latitude and 611˚ and 751˚ longitude covering an area of 79.6 million hectares. The country inherited highly variable topography, climate, and culture. The climatic variability is expressed by humid zones in the northeast to hyper-arid in the southwest and west. The major part of the country is classified as arid to hyper-arid as shown in Figure 1 (Roohi, et.al. 2002).

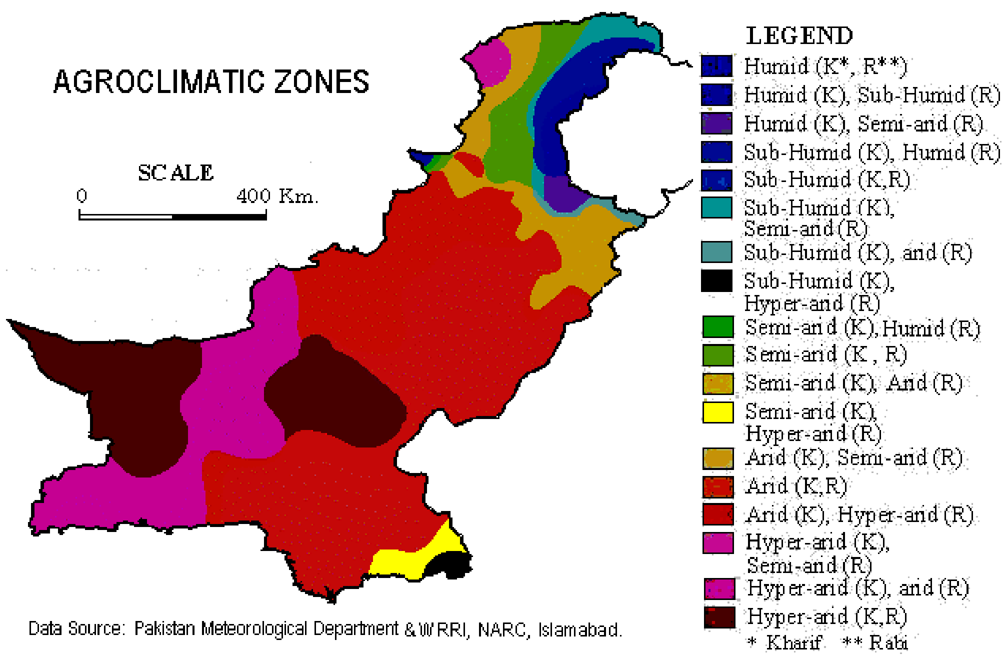


Figure 1: Agro-climatic Variability in Pakistan

The country's high mountains comprise the western end of the Himalayan range and some parts in the Hindu Kush and Karakoram ranges. Some of the lower mountain ranges in the northeast receive high monsoon rainfall in summer and snow precipitation during winter. The snow and glaciers in the northern high mountains are the major source of water for the irrigated agriculture in the Indus basin. The climatic variability coupled with the high dependency of agriculture on the irrigation water results in the complex cropping system (Figure 2). Some of the major cropping sequences include Rice-Wheat, Coarse grain-wheat, cotton-wheat, maize-wheat, sugarcane-wheat and groundnut-wheat. Within these cropping systems there is further mix of other crops in both summer (*Kharif*) and winter seasons (*Rabi*). Cultivated areas in Pakistan are classified as canal command, tubewell command, Sailaba, and Barani. The total cropped area in 2005 was 22.51 million hectares (Table 1).

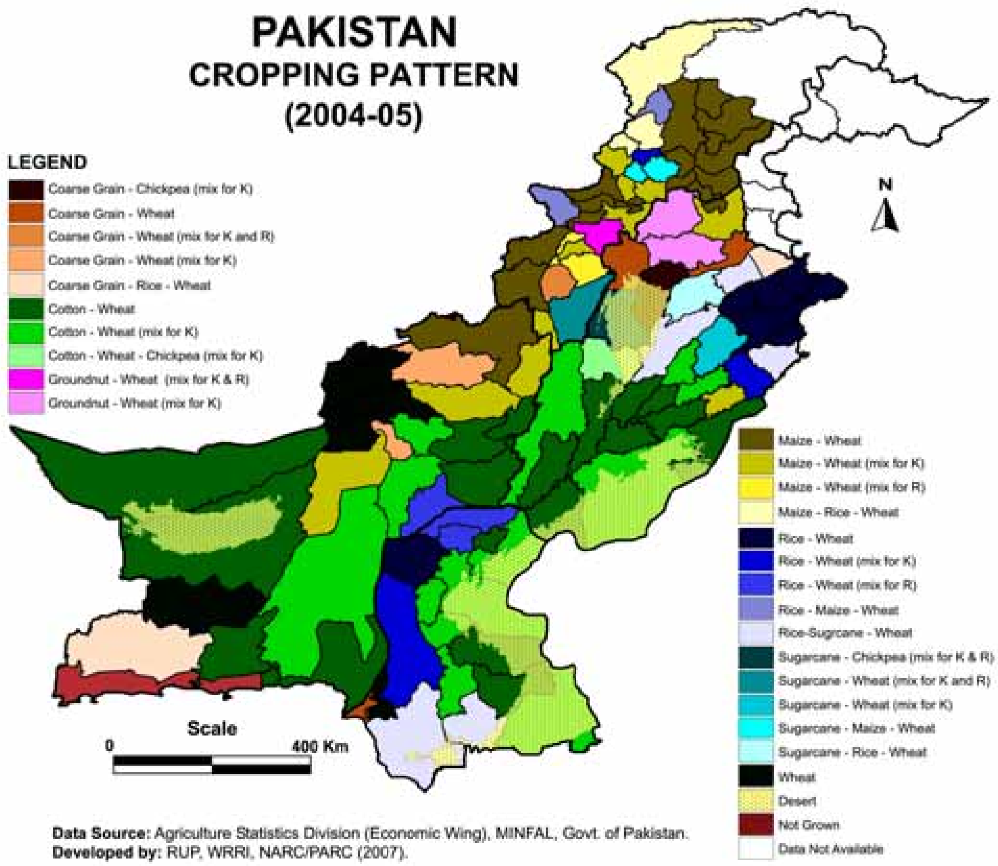


Figure 2: Variability in Cropping Patterns

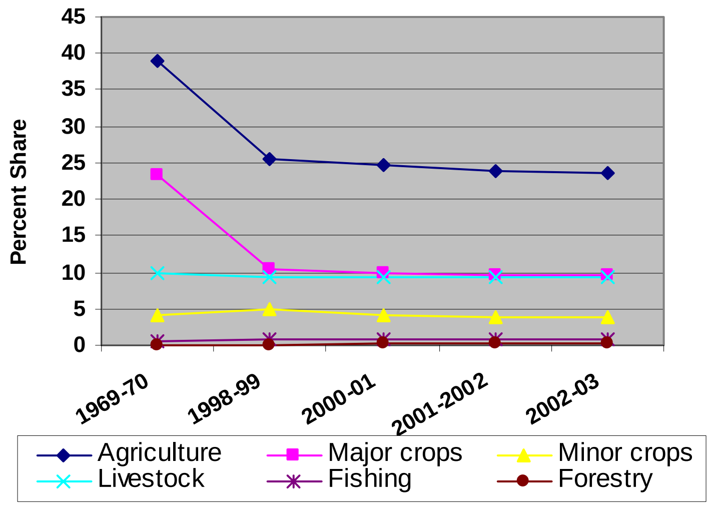
Source: Resource Use Planning Programme, WRRI, NARC, Park Road, Islamabad, Pakistan

Table 1: Land utilization statistics (million ha)	
Geographical area	79.61
Forest area	4.01
Not available cultivations	24.32
Culturable waste	9.00
Cultivated area	22.15
Current fallow	6.61
Net area sown	15.54
Area sown more than once	6.97
Total cropped area	22.51
Source: GOP, 2005	

Agriculture contributes about 24% to the GDP of Pakistan and provides employment to 48.4% of the labor force (EAW, 2003). The country's agricultural production system is complex and consists of a mix of crop and livestock production and so are the contributions of various sub-sectors to GDP (Figure 3).

The farms of an area of less than 5 hectares constitute 39% of the cultivated area, and 81% of all farms in the country fall in this category. About 12% of farms have an area of 5 to10 ha, and such farms cover 22% of the total cultivated area. Only 7% of all farms are over 10 ha in size, but these account for 40% of the farmed area. The variability in size of land holdings are reflected in diverse land use and cropping systems driven by varying investment capacity of different farmer groups.

Figure 3. Share of Agriculture in GDP



There is an emerging trend that overtime percent of farm area cultivated and area net sown have been increased (Table 2). Landuse intensity and cropping intensities have also been increased from 84 and 103 percent in 1960 to 85 and 142 percent in 2000 respectively. There are three types of tenures in Pakistan namely owner cultivator, owner-cum-tenant and tenant. The predominant (78 percent) are owner farmers operating 73 percent of farm area in the country whereas 8 percent are owner-cum-tenant and 14 percent tenant operating 15 and 12 percent farms area in the country respectively.

Table 2: Land utilization overtime from 1960-2000 (%)

Land use	1960	1972	1980	1990	2000
Farm area cultivated	76	83	83	82	81
Area net sown	86	92	95	96	94
Intensity of land use	84	89	89	87	85
Cropping intensity	103	111	122	137	142
Source: GOP, 2005					

Almost a third of Pakistan’s total area is classified as rangeland (GOP/RCA, 1992). These rangelands support two-thirds of the entire population of sheep and goats and over half of the cattle population of the country. Millions of herders and pastoralists depend on rangelands for their livelihood.

Livestock farming plays a significant role in the economy of Pakistan. Livestock is still a major source of fertilizer for crop production, power for farm operations, and fuel for cooking, and is an are easily convertible mobile asset in times of emergency. Most of the buffaloes, however, are the primary milk producing animals and are found in the irrigated areas, although in recent years, herds are also being raised in peri-urban areas.

With this background having complex climate, agricultural production and cropping system variabilities and tenure systems it is highly complex to address the farm mechanization issue especially in the context of changing climate scenario.

2. Climate change and challenging issues in Pakistan

Pakistan's status as a developing country dependent mainly on agriculture makes it particularly susceptible to the effects of climate change. Added to this is the fact that like most other developing countries, Pakistan does not have adequate monitoring systems for the prediction of likelihood of occurrence of extreme events, or the assessment of possible changes in weather patterns, thus making the task of developing short term response or disaster mitigation strategies extremely difficult.

The climate change research in the country is in its infancy and is mainly focused to understand the past trends and current variabilities. In general the focus of climate change research is towards ***Physical Indicators*** including climatic parameters, water resources, glaciers, glacial lakes and surges and ***Biological Indicators*** including agriculture and natural ecosystems.

In a comprehensive study using high quality toposheets, remote-sensing data of Landsat-7 and Digital Elevation Model, the inventory of glaciers and glacial lakes was completed and the potentially dangerous glacial lakes were identified (Roohi, et al.). Over a vast area of Indus River Basin 5,218 glaciers and 2,420 glacial lakes are identified out of which 52 are characterized as potentially dangerous lakes. Historical record of glacier fluctuations in Himalayas and Karakoram indicate that in the late nineteenth and early twentieth centuries the glaciers were generally advancing followed by predominant retreat during 1910-1960 (Mason 1930 and 1935 and Goudie et al. 1984). In the last 100 years, 26 sudden, rapid advances have been reported involving 17 glaciers (Hewitt, 1969).

Analysis of past climatic data depicts that climate is changing (Farooq and Khan, 2004). There is temporal as well as spatial variability in the rate of change and the nature of resulting impacts affecting all aspects of life. In the context of climate change there is a need to develop and implement incremental adaptation strategies and policies to face the realities associated with climate change. It is observed that the maximum and minimum temperatures have dropped in the north eastern mountains while there is an increase in western parts of the country. Generally summer (April-May) maximum temperatures have increased in all the regions except in the coastal belt while minimum temperatures show a mixed trend with increasing trend in Balochistan plateau, coastal belt and central and southern Punjab. Precipitation has increased in all the regions during the monsoon period except in western Balochistan plateau and coastal belt where it has decreased. In Pakistan there is generally a rise in temperature of 0.5 °C to 1°C in the northern arid mountains, western dry mountains and coastal areas (Ahmad S., A. Bari and A. Muhammad, 2003). In the monsoonal zone, generally a decrease or no change in temperature was observed. Furthermore, there was an increase in extreme temperatures in the arid environments comprising broadly the plains, dry mountains and coastal areas. Increase in extreme annual rainfall was observed in the hot humid, sub-humid and semi-arid environments, whereas decrease was observed generally in cool humid/sub-humid regions, dry mountains and coastal areas.

Looking at the water resources, there is a decreasing trend in flows of river Indus and Kabul, whereas a mixed trend was observed for the rivers Jhelum and Chenab (Ahmad S., A. Bari and A. Muhammad, 2003). For the western rivers, the analysis of both winter (*Rabi*) and summer (*Kharif*) seasons indicated a reduction in river flows during 1968-97 from that of 1937 -67. Extremes of water availability were also reduced during the same period. Due to climate change the snow avalanches and GLOF events were observed at high elevation (>3500 m), landslides, debris flow, flash floods at medium elevation (500-3500 m) and floods in lower valleys and plains were common.

Amongst the possible effects of climate change is the likelihood of increased frequency, and severity of occurrence of extreme events such as floods and droughts. Increased intensity of such exogenous shocks combined with a growing population may lead to increased displacement of rural communities, human migration, and rapid, unplanned urbanization. The people and animals that survive are faced with starvation because foodstuffs and forage may not be immediately available in sufficient quantities.

Intensive animal production presents many challenges to environmental management. Potential emissions of pollutants to the atmosphere, soil and water may emanate from a variety of sources at the site of production facilities, as well as from off-site areas, such as agricultural land on which manure is applied.

Due to population increase, the country is spending around US$ 1.0 billion annually for the import of food items. The climate change would further aggravate these problems as the irrigated agriculture in semi-arid and arid environments is already operating under extreme high temperatures (Ahmad, 2005). It is stipulated that the increase in temperature of 0.9 °C and 1.8 °C would further shorten the growing season length of cereals (wheat, rice and maize) leading towards shift in potential area of these crops. The increase in crop evapo-transpiration would require additional water for growth and cooling in an environment where water is already in short supplies. The increase in utilization of marginal quality groundwater would further add towards secondary salinization of soils. It is generally considered that climate change might have a positive impact on mountain agriculture (increase in yields of food crops) because of higher CO_2 concentrations, reduction in Growing Season Length (GSL) and thus wheat cultivation for grains would be possible above 1500 meters. Other crops and fruits might also be benefited. The natural ecosystems are not exempted from the climate change impact. In a study of mountainous ecosystems it is concluded that overall impact of climate change on the forest ecosystems could be negative (Siddiqui, 1999).

In summary, the climate change can have the following effects especially on the agriculture:

Potential Vulnerability to Heat Stress

This would not only affect the growth, maturity and productivity of crops but also would require additional amount of irrigation water to compensate heat stress rather cooling of crops might become an essential element of the crop production system.

Potential Shifts in Spatial Boundaries

A small increase in mean temperature can translate into much higher ambient temperatures in the planting and growing periods, which can affect a shift in potential boundaries.

Changes in Productivity

The simulations showed that a temperature increase in the three selected locations, which consist of semi-arid and arid regions, might result in minor reductions in the grain yield.

Changes in Water Use

The temperature increases coupled with variations in rainfall can increase the net irrigation water requirements of sub-humid, semi-arid and arid climatic zones.

Changes in Land Use

The projected increase in temperature by 2050 would reduce the growing season length and productivity of all the major cropping systems, but might provide more time for preparation of land for the next crop and have implications for land use in agriculture

Projected Production of Agricultural Commodities

Changes in climate especially increase in temperature coupled with decrease in rainfall would have a negative impact on the future projections of production of major crops.

3. Policy Initiatives

Pakistan is a country that contributes very little to the global GHG emissions, but nonetheless views climate change as an issue not only requiring international cooperation but also a pro-active policy at the national level. It is with this objective that Pakistan has embarked upon dealing with an issue that threatens the predominantly agriculture base of the economy and has implications for livelihood and survival of a population of over 140 million people.

Pakistan’s environmental policy and management framework is based on the Pakistan Environment Protection Act 1997 (PEPA), which in turn replaces the Pakistan Environmental Protection Ordinance promulgated in 1983. Major policy initiatives in the environment sector have been the enactment of National Conservation Strategy (NCS) in

1992. Forestry Sector Master Plan and NCS plan of Action and the finalization of a National Environmental Action Plan (NEAP) in February 2001.

The Government of Pakistan attaches high importance to the development of renewable energy resources and has recently constituted a high-powered alternate energy board to advise the government on cleaner forms of energy. The energy sector is the single largest source of greenhouse gas emissions. As such, it is also the sector which is believed to have the greatest potential for development. The country has vast potential for renewable energy development like hydropower, wind and solar energy. In order to meet its growing energy needs, Pakistan requires specific assistance in environment friendly technologies and renewable energy development to embark on a development path that is not only sustainable but also helps the country in meeting the objectives of international commitments. Given the contribution of energy sector in the economic growth and its GHG mitigation potential, it has been recognized that such assistance will be required both technically and financially in the area of renewable energy development.

4. Farm mechanization

In the early twentieth century, even in industrialized countries, production of the world's food supply required the labor of at least half the population. Today, thanks in large part to advancements made by biological and agricultural engineers; developed countries can accomplish this using only a slim 2% of their populations.

Now, new challenges present themselves. As world population swells, more food, energy, and goods are required. The limited natural resources demand to produce more with less so that higher productivity does not degrade the environment, and also search for new ways to use agricultural products, byproducts, and wastes. Biological and agricultural engineers are responding with viable and environmentally sustainable solutions but at the same time new challenges are emerging with the changing climate requiring shift in prioritization.

The Farm Machinery Institute of national Agricultural Research center has been working for the promotion of agricultural mechanization in the country through designing, performance evaluation and commercialization of appropriate farm machinery. It is equipped with required facilities of designing, prototype fabrication workshop, and farm machinery testing laboratory and testing yard. Its activities have been mainly grouped in crop establishment engineering; harvesting and threshing engineering; post harvest engineering; industrial and mechanization research and farm machinery testing and standardization. Recently, FMI has developed and commercialized paddy transplanter and zero-till drill and is working on pneumatic row crop planter, hold-on paddy thresher, solar dryer for fruits and vegetables and dual mode drill.

5. Needs for Adjustment in Farm mechanization

After reviewing the situation under global climate change, the two main priority areas to address immediately are water resources and energy There is need for evolve a mechanism for integration of farm mechanization, global climate change, and water management research areas/ interface laid out agricultural engineering in support of the Kyoto Protocol. In the reducing water resources and increasing temperature situation the immediate need is to efficiently utilize the resource. There is an immediate need to first characterize and classify the areas according to their susceptibility to climate change so that mechanisms could be tailored to address the most crucial issue. The best agricultural engineering solutions could be system based rather than component based. Since the climate change is regional issue, therefore, multidisciplinary regional effort requires partnership in strategic research among different national and international institutions with complementary strengths.

The existing agricultural engineering and farm mechanization needs could be focused in the following areas:

Water Resources

- Better techniques for determining crop water requirements or irrigation demand preferably sing RS/GIS techniques and designing irrigation systems accordingly.
- In the shifting rainfall pattern the cropping calendar is distorted. The water injection cum fertilizer drill can be one of the solutions for timely sowing of particularly rainfed crops.
- The overall irrigation efficiency of the Indus basin in Pakistan is around 36% which means only 1/3rd of surface water is available for crop consumption requirements. To address this low efficiency the following research activities could be focused:
  - Development and commercialization of low-cost geo-membrane liners for lining of canals and watercourses
  - Water efficiency can substantially be improved by leveling the field properly. Local manufacturing of cost effective laser levelers could be given priority
  - Development and of water and energy efficient irrigation systems. Pakistan has already commercialized the sprinkler and drip irrigation systems and there are several local manufacturers marketing the systems. However, there is a need for quality control. The efficiency of the pumping systems needs further improvement. For large farms there is a need for local fabrication of Central Pivot
  - Machinery for innovative surface irrigation
  - Development of skimming wells and energy efficient pumping systems
- On-farm rainwater harvesting and storage structures.

Energy

- Improvement in fuel efficiency in agricultural machinery
- Commercialization of wind power potential
- Development and commercialization of cost effective solar panels

Farm Operations

- Minimum tillage to reduce the effect of temperature rise on the increase of soil temperature and improve soil structure.

Livestock silage

- Environmental management systems and preventing pollution for intensive animal production units

- Biogas production units
- On-farm livestock waste management
- Animal housing and storage structures with ventilation systems, temperature and humidity controls, and proper waste management.

Nursery & Greenhouse Engineering

- For off season vegetables and nursery development cost effective greenhouse structure needs to be developed.
- Equipment for hydro-ponic cultivation

6. Recommendations

As the climate change research outcome is getting clear and there are visible evidences of impacts of climate change on agriculture, following are some of the suggestions to consider:

- Strengthen international partnerships for joint research and development in agricultural engineering and farm mechanization to address the expected threats posed by climate change.
- The regional information/data sharing should be encouraged.
- Education in climate change may be introduced in curricula at various levels.
- Since the impact of climate change is complex, therefore, system approach is required to integrate the entire farm activities.
- Water management and cost effective efficient irrigation systems for enhancing water use efficiency and reducing the heat stress are required to be designed under increasing crop water demands.
- Tapping renewable energy sources and improving fuel efficiency in agricultural machinery
- New tools and techniques like Geographic Information System, Remote Sensing and simulation modeling needs to be introduced for characterization and system analysis which is not only cost effective but efficient as well.
- Facilitate greater adoption of scientific and economic pricing policies, especially for water, land, energy, and other resources.

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