Reaching Cotton Farmers with Agrometeorology Services

1. AgriSurge Innovation Challenge:

Climate conditions in Pakistan are changing and will impact future production of all food and feed crops. The general circulation models (GCM) estimated an average increase in global surface temperature of about 4°C (2.9-5.5°C) and an increase in extreme weather events. Climate plays a fundamental role in agricultural production systems, and is most open to threats posed and opportunities created by climatic change. Agriculture is fully dependent on microclimate, weather and ecological environment. Therefore, these changes in global climate such as rise in temperature, shift in rainfall cycles and intensity resulting in crops failure, disturbance in different growth stages, development and yields.

Cotton (*Gossypiumhirsutum* L.) is known as "White-Gold" and is a most important fiber, oilseed and cash crop in Pakistan. It is a major summer (Kharif) crop of Punjab (75%) and Sindh (25%) provinces in the country. Approximately 1.5 million smallholder farmers rely on cotton for a livelihood, and cultivate on 2,950,000 hectares of land. The increases in temperature and shift in rainfall cycle is affecting cotton growth and threaten the sustainability of cotton production and quality, especially in South Punjab and Sindh in Pakistan. The mean temperature at the global level has increased by 0.85 °C since the industrial revolution. The average surface temperature of these regions has increased at a rate of 0.25 °C per decade.

Cotton production has already declining in Pakistan, expected to decline in countries like China and India with the exception of the United State, Uzbekistan and Australia. Various studies have shown the potential threats of climate change to crop production. According to figures issued by Pakistan Cotton Ginners Association (PCGA/2016), cotton output reduced to 5.951 million bales in Punjab from 10.7 million bales harvested in 2017, which count 33.9% overall decline in cotton production. Cotton growth and development is highly influenced by rise in temperature and shift in rainfall cycles. The negative impacts of physical variables such as land-use, irrigation, NPK fertilizer balance reported highly significant.

Escalating temperature increases evapotranspiration rates sometimes causing severe water stress and fruit abscission thus reduce the plant growth and yield. The impact of high variations in precipitation from mean value negatively impacts cotton productivity. In Punjab, average lint (%) and boll weight (g) of cotton is low due to high temperature and water shortage. High temperature also makes the crop more vulnerable to pest attack and usual response of crop is loss of vegetative and fruiting parts. Due to high temperatures in arid regions, cotton crop emergence and early establishment of seedlings are adversely affected. Extremely high temperature during cotton flowering and boll stage in South Punjab causes severe boll abortion observed often in recent years.

Our computer-based modelling projections of 15-agrometeorology stations showed that the growing duration during the sowing-boll opening stages and drilling-harvesting were reduced by was reduced 2.30-5.66 days decade-1 and 4.23 days decade^{-1}. Temperature rise has advanced the planting dates, sowing-emergence, 3-5 leaves, budding-anthesis, full-bloom, cleft-boll, boll-opening, boll-opening filling by 24.42, 26.19, 24.75, 23.28, 22.62, 15.75, 14.58, 5.37, 2.85, 8.04 days. Further, our findings exhibited that climate stop-growing becomes 2.16 days premature, and the time-scale has been delayed for 8.2, 2.4, and 5.3 days in the 1970s, 1980s, and 1990s. Models quantification of Pakistan revealed that sowing, emergence, anthesis, and maturity stages were negatively linked with temperature -2.03, -1.93, -1.09, and -0.42 days °C^{-1}. The negative impact might be mitigated by adaptation to the climate-smart cotton production system by improving agrotechnological services. Research reported that a rise in temperature even for a short time period distresses crop growing, and escalation in air temperature decreases the development of shoots, and it turns to a reduction of root elongation. Warming at 38°C in rice crop affect plant height, smaller roots, and increase in temperature at the booting stage resulted in pollen abortion [43]. Furthermore, higher temperature disturbs the photosynthesis and respiration. Higher soil temperature reasons stem scorches (stem girdle) at the ground level, i.e., cotton.

Cultivated area and production of cotton is decreasing along with poor quality and low price in market. Smallholder farmers are at the front line of stakeholders being affected by yield decline. There are many factors involved in this scenario but of these factors lack of education to adapt changing climatic condition in agriculture farming of major importance. There is need to upgrade the knowledge and techniques of agriculture experts and extension worker. Farming communities and particularly small farmers are reluctant, resistant to change and adopt measures of risk aversion. Furthermore, lack of appropriate weather information, to plan tillage and application of balance fertilizers, design and suitability of farm practices contribute to low productivity of cotton farms. Major problem is lack of coordination and information sharing between meteorology institutes and farmers.

The advancement in technology has been a major catalyst in disrupting the Indian economy positively. But when talking about the economy, one of the primary contributors is the agriculture sector, which desperately needs technology to rescue farmers in Pakistan, boost revenue, production and tackle issues. Given that the lives of farmers and the food economy that impacts the whole population are at stake.

2. Proposed Solution:

Efficient crop production technology is based on a right decision at right time in a right way. Despite the existence of various cultural practices and strategies as well as the institutional research, climate and weather unpredictability has continued to present new challenges to organized response farming. Farmers need a helping hand when it comes to input material and they most often rely on middlemen in the supply chain for this part of their business. This modelling results will provide analytics to farmers based on soil tests, past crop history, and financial data, but also operates physical centres in the villages to provide farm advisory, deliver quality seeds, pesticides, and fertilizers to the farmer's doorstep.

Crop Modelling Tools: Crop simulation models (CSM) or growing the crop on the computer are processes of crop growth and development as a function of weather conditions, soil conditions, and crop management. Typically, such models estimate times that specific growth stages are attained, biomass of crop components (e.g., leaves, stems, roots and harvestable products) as they change over time, and similarly, changes in soil moisture and nutrient status. We will apply two type of crop models a) Crop Weather Models; b) Crop Yield Models. Following modelling tools will be used:

#	Models & Tools	Functions
1	APSIM (Agricultural Production Systems Simulator)	Link climate and weather forecast, crop cycle and fix sowing dates, calculate water

		demand, Fertilizer and soil management
2	DSSAT (Decision Support System for Agrotechnology Transfer)	Apps for climate variability and weather, soil, genetic, crop management, simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics
3	MP406 (Sensors)	Climate-smart irrigation scheduling, plants water requirements and drought stresses, available moisture monitoring
4	Automatic Weather Station (AWS)	Real-time cloud weather data, micro-climatic conditions, precision agriculture

Simulation models are widely used for making decision support especially under sub-optimal climatic conditions for yield improvement. The impact of uncertain weather conditions on cotton production can be explored with the aid of such models. These model tools are useful to monitor crop performance and predict crop responses to climatic stresses such as drought, high temperature variations nutrient depletion, pests and diseases, water logging, changing atmospheric CO_2 concentrations, and precipitation. Suitable crop models and remote sensing etc. are helpful to maintain crop water balance, improve fertilizer use efficiency, as well as can provide information or predict the results about the growth and yield when the current and past weather data is used. Integrate crop model, cloud data analysis and real-time growth monitor provide a useful tool for smart management of cotton production.
Computer-based crop models and sensors will measure multiple dynamic variables including micro-climate, soil, and crop conditions. It leverages machine learning to transform this data into farm-level predictions, anticipating various risks while helping horticulture farmers reduce input costs, optimise crop protection, irrigation, and crop nutrition. Farmers are required to pay a monthly subscription depending upon the farm size and crop for the time their crop is active.

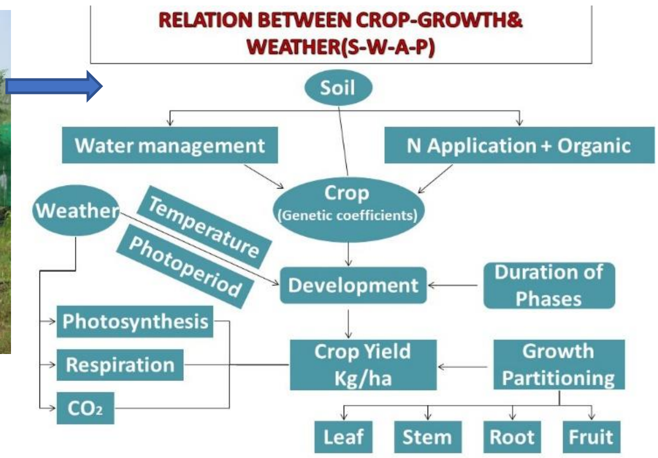
Agrometeorological Education: For optimizing crop growing season considering solar radiation, air temperature, precipitation, wind, humidity etc. agro-meteorology considers and assess the suitability of these parameters in a given region for maximum crop production and economic benefits. To reduce risk of crop failure on climatic part, so as to get stabilized and sustainable yields even under weather adversity, suitable crops/cropping patterns/contingent cropping planning can be selected by considering water requirements of crop, effective, rainfall and available soil moisture. Management of crop involves various farm operations such as, sowing fertilizer application, plat protection, irrigation scheduling, harvesting etc. Agro-meteorology and crop modeling can help to understand crop-climate relationship so as to resolve complexities of plant process in relation to its micro climate. Climatic extremities such a frost, droughts, hails storm, high winds can be forecasted and crop can be protected. Soil moisture can exactly be determined from climatic water balance method, which is used to diagnose the soil moisture stress and drought enabling the growers to take necessary protective measures such as irrigation, mulching, application of anti-transparent, defoliation, thinning etc.

3. Product/Technology:

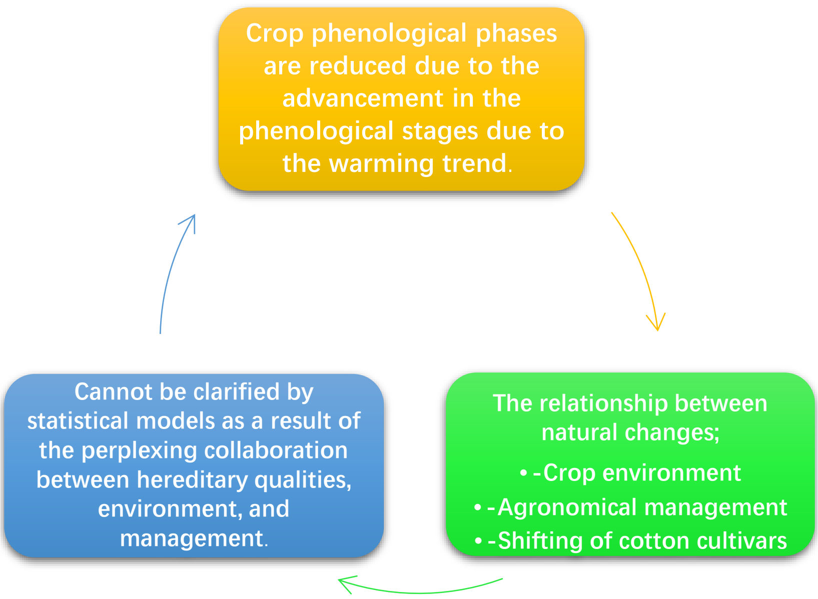
Simulation models of crop growth and production provide a widely accepted tool for assessing agricultural production opportunities in different agro-ecological zones in response to weather and management, for identifying ideotypes that are well adapted to certain agro-ecological conditions, for better understanding interactions between genotypes, environment and management.

Right from ensuring that our farmers receive complete monitoring of growing practices, to implementation of models' simulation, right till using information to give transparency to our farmers and consumers. The following models will be used to develop the simulations to predict the crop sowing dates, water and fertilizer requirements and different cultivars yield potential which will be translated into local languages (Urdu, Punjabi and Sindhi). The technical information will ultimately be educated and help farmers to plan and practice cotton production technologies.

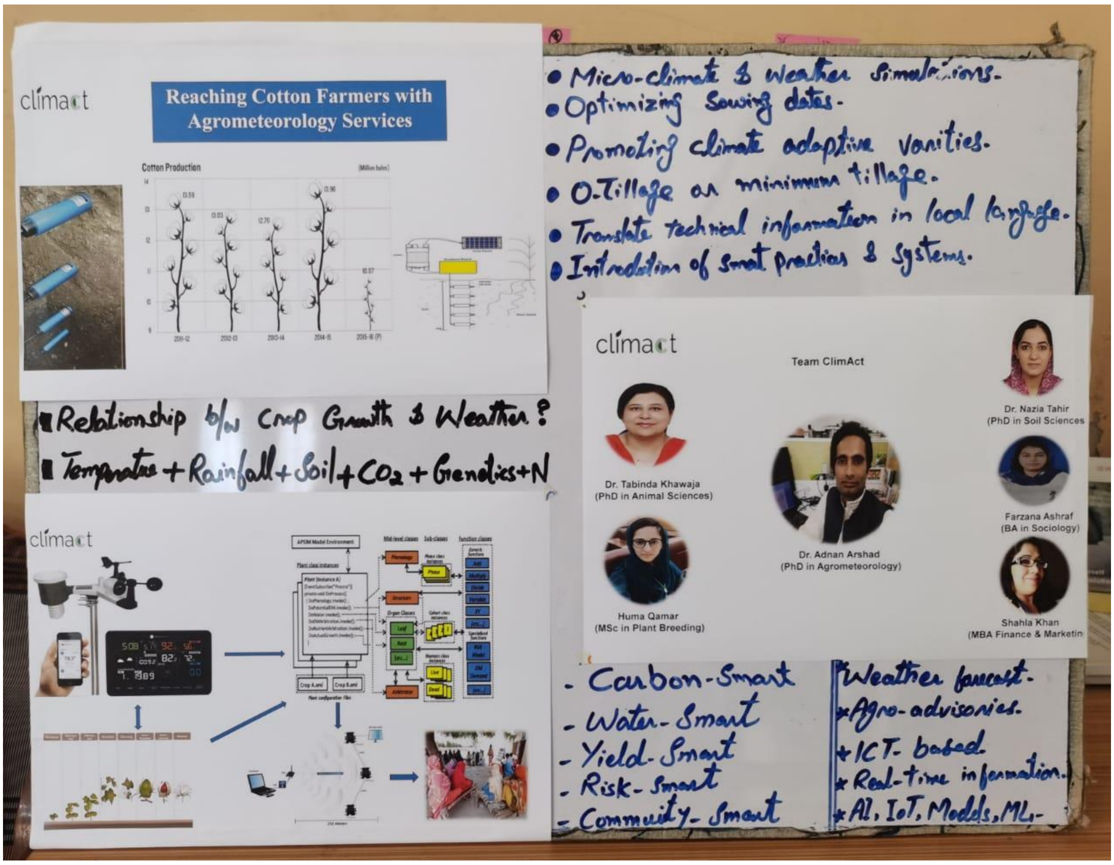
Step 1: Cotton crop relationship with climate change and extreme weather conditions in Pakistan



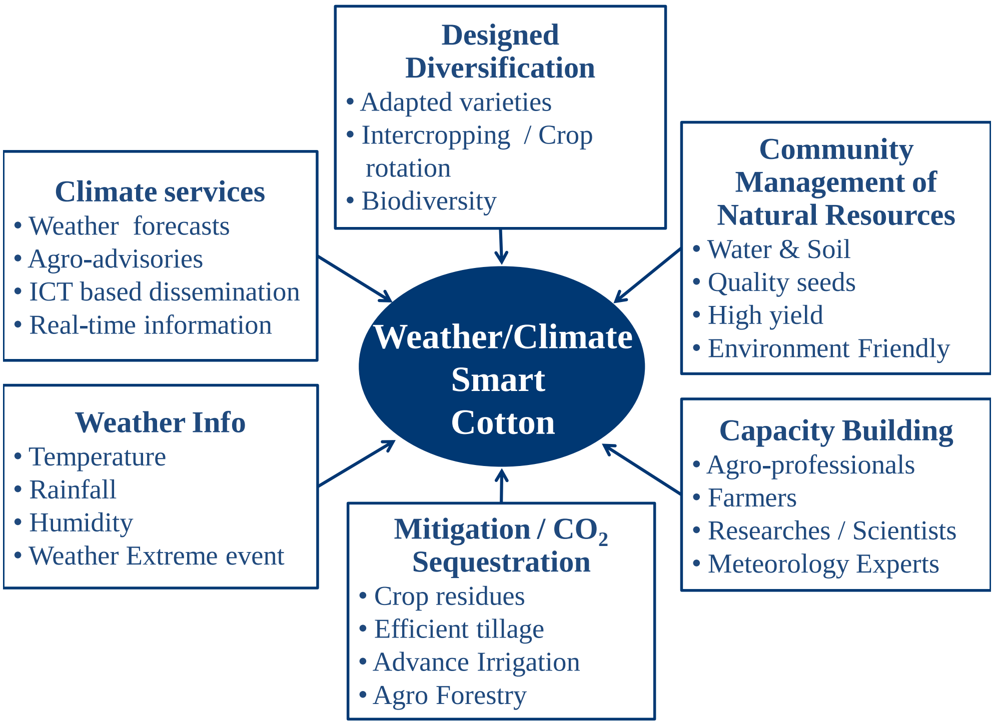
Step 2: Phenology stages vulnerable to temperature and rainfall as Temperature (°C) and precipitation (mm) are the most important factor (automatic weather station data)



Step 4: Framework of Solution



Step 5: Sustainability Framework



Risk Mitigation plan

Likelihood/Impact	High	Medium	Low

Risk	Likelihood of occurrence (color code)	Impact (color code)	Planned measures for mitigation
Covid-19-related risks			
COVID-19 pandemic			We will organize virtual trainings or follow social distancing policy.
Programmatic risks			
Availability of project sites			We proposed a project location where the organization has over 15 years of experience.
Institutional risks			
NOC from Government			We have a valid MOU with government to execute project activities.
Fiduciary/Financial risks			
Timely transfer of funds			We will make sure availability of enough funds for continuation of project activities.

4. Sustainability:

Changing markets, technological innovation and organizational progress in recent years have increased the intensity and scale of agricultural land use. The project will strengthen collective efforts by researchers and farmers, government departments and local stakeholder and social workers and other concerned to join hands to address the serious challenges of energy and their cost-effective solutions.

In the start we will utilize the award amount to develop our system and provide services to the small farmers in the area. After the success and progress we will approach to the progressive farmers and provide services with charges.

During the project, Team will help youth group students to form a network or association of all the participants and help them to register with a relevant body so that after the program they can continue their work as a group and be linked with each other through information and meetings. This will also allow sustainability of this modelling training program and PODA organization will link them with local farmers networks, unions and other resources that can support them further. PODA will engage communities and government institutes in pre- and post-project period.

The project interventions will benefit the target women farmers, youth and their families after the project because the improved reading competencies will ensure climate-smart education for better production to ensure sustainable agriculture.

5. Commercial Viability:
Our solution will be implemented first time in Pakistan. But previously, it is has shown very good results in China and Nepal under my supervision. I have four years of professional working experience in different countries to install and run this solution. Our targeted users will be 1000 cotton producing farming communities particularly women and youth groups in Punjab (500) and Sindh (500). Among total 50% would be women farmers.
After the one or two growing seasons of the cotton crop according to the "Crop Models" farmers will get significant increase in yield with minimum input cost. Crop will be more climate resilient and resistant to the biotic and abiotic stresses. Farming community directly or indirectly will get the maximum benefit in term of high yield and earn good price at the end.
We will implement this project as "Pilot Project" and utilize the award amount to develop our modelling simulation and technical literature in local languages. After the project we will connect with other local organizations, provincial governments and big farmers to buy our modelling services to plan their crops without effecting soil health under the limited water resources.
The major cost will be to setup of Automatic Weather System to support our Models. But it is one-time investment, afterward we can sale our services to other farmers in the area.
We will establish one model farm and install all the equipment's and tools on the ground bases and let others to see. We will intend to reach our farmers by "Seeing is Believing". So, our demonstration model farm will be our teaching and capacity building classroom for our future customers.

6. Team:
Team "ClimAct"is a group of young Agri-graduates, and early carrier researcher working in different disciplines of agriculture and climate sector in Pakistan. Our team has implemented a project on "Rainwater Harvesting for Agriculture" in 2015/16 in Pakistan, funded by World Water Forum. Our group is well connected and motivated to support small farmers' particularly women farmers and youth in rural areas of Pakistan.

- Dr. Adnan Arshad, PhD in Agrometeorology from China Agricultural University is the group leader of team "ClimAct". He has four years of research experience in climate-smart modelling and agrometeorology with practical work in China and other countries (Malaysia, Brazil and Srilanka). For further information about visit www.adnan99.com
- Dr. Nazia Tahir is working as researcher in soil water and nutrition modelling and application of sensors to facilitate farming communities. She will run the models and process the data to simulate the results.
- Ms. Shahla S.Khan has MBA degree in agriculture financing and marketing. She is working as country representative of YPARD Pakistan. She will help us to outreach our solution in next step and do the translation work.
- Dr. Tabinda Khawaja is working as consultant in livestock and dairy sector and providing technical skills to startup our project.
- Ms. Huma Qamar is a plant breeder and working in Ayub Agriculture Research Institute in Faisalabad. He will support us in identification of weather adaptive cotton varieties.
- Ms. Farzana Ashraf is working with PODA Pakistan. PODA organization will help us to connect with farmers networks. PODA organization has 15-years of

working in Pakistan so Ms. Farzana will connect our solution with women farmers and youth in the field.