Computer Science Department

COURSE

Technical and Business Writing

TITLE

ROLE OF SMART FARMING IN AGRICULTURAL MANAGEMENT IN PAKISTAN

PREPARED FOR

Miss Sabeen Amjad

BY STUDENTS

1. Khawaja Abdullah (20K-0385)
2. Basil Ali Khan (20K-0477)
3. Ahad Shaikh (20K- 0319)
4. Sohaib Ashraf (20K-0488)
5. Muhammad Shahzaib (20K-1067)
6. Ali Jodat (20K-0155)

TASK

Short Report

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Abstract (Abdullah, 20K-0385)

Agriculture accounts for 21% of Pakistan's Gross Domestic Product (GDP). Using conventional farming techniques have reduced crop productivity and quality of crops which results in less exports of agricultural products of the country. Traditional methods involve constant monitoring of the farm that is exhausting for the farmers which reduces their productivity. The solution lies in using modern technology and advancement in Artificial intelligence in agricultural sector of Pakistan. Developed countries have adopted this smart farming concept long time ago and are already taking benefit from it. This research aims to propose smart farming model in Pakistan and how Internet of Things (IoT), and Artificial intelligence fields, like Machine Learning and Computer Vision, can be combined to provide a suitable solution to farmers to increase the crop yield in less time according to Pakistan's need and environment. Quantitative research methods will be used to identify best Machine Learning algorithms for farming work like pest or disease detection and compare the results with manual work done by farmers while qualitative methods will be used to explore the potential of using 5G for agriculture sector in Pakistan. Thus smart farming provides a feasible solution to farmers to help boost the crop productivity and quality of crops in Pakistan.

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1. Introduction (Khan, 20K-0477)

Demand for food production also rises as a result of the growing population. Agriculture is still a primary source of likelihood and plays an important role in Pakistan's economy Pakistan's agricultural contribution to Gross Domestic Product (GDP) is 21% with an annual growth of 2.7% [1]. Farmers in Pakistan use traditional methods which are outdated and time consuming. Conventional farming practices lead to erratic production, overutilization of resources, poor quality of the final product and wastage of resources. To increase the standard of farming in Pakistan at par to the developed countries, smart farming can be used for more effective farming.

Smart agriculture can address various issues related to crop production. The Internet of Things (IoT) technology is able to link various remote sensors such as robots, ground sensors, and drones [2]. The Internet of Things (IoT) is an intelligent and promising technology that offers unconventional and practical solutions in many areas including agriculture. Since IoT devices can be used to monitor temperature, humidity, and other variables, they can be a big help in increasing production and yield in the agricultural industry [3]. IoT sensors are capable of providing farmers with information about crop yields, pest infestation, disease detection and qualitative classification of crops which will rise up the quality of farming techniques in Pakistan. Several agricultural robots are already being made and perform one or more functions, as shown in Figs. 1 and 2.

In this research, we will integrate IoT with Artificial Intelligence (AI), computer vision, and machine learning to develop a smart agricultural model that will help Pakistani farmers become more productive and expedite their job. We hypothesize that there is a positive association between the use of smart farming methods in Pakistan and increase in the yield and quality of the crops in lesser time. Both quantitative and qualitative methods will be used in this study to check our hypothesis. With some drawbacks of the 4G technology, discussed later in the research, we will investigate the use and potential of 5G in our smart farming model, and how Computer Vision and Machine Learning Algorithms will be used to find the best and fastest method for its use in smart farming.

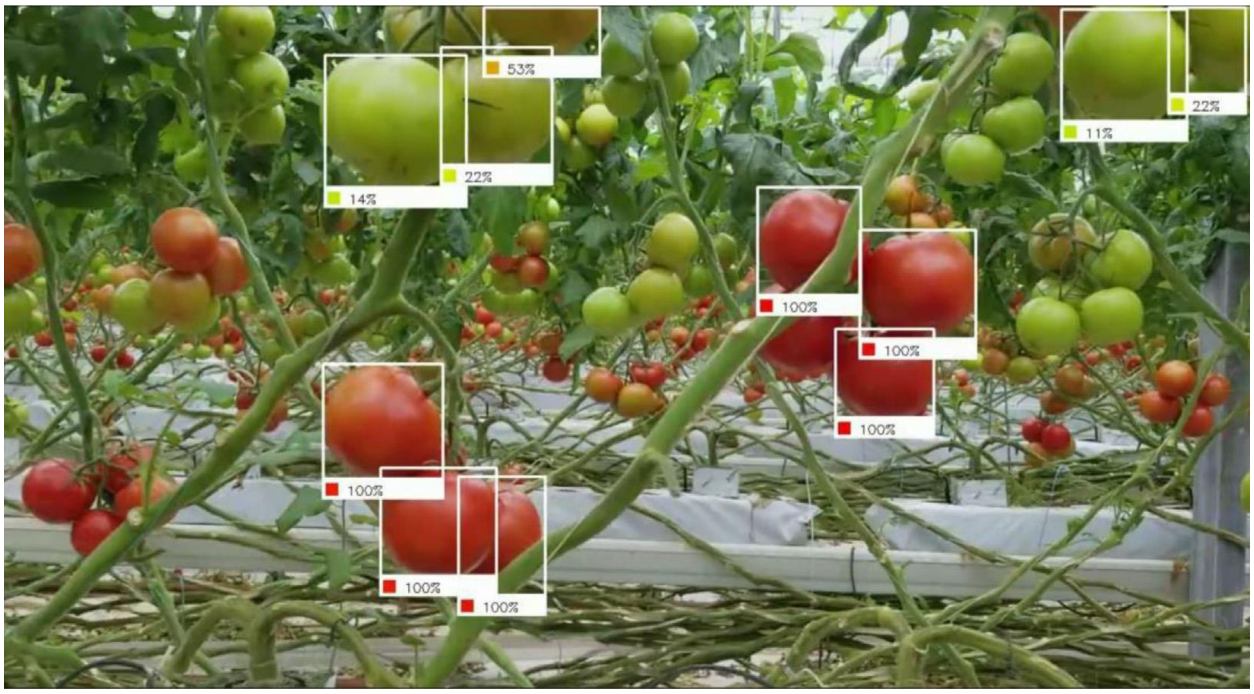


Fig. 1. Tomato harvesting by robots [2]

Fig. 2. An Autonomous robot for weed removal [2]

2. Objectives and Research Questions (Khan, 20K-0477)

Agriculture is the backbone and most important source of livelihood for people in rural areas of Pakistan. Pakistan is the world's sixth most populous country and its population is growing at a rate of approximately 2% per year. Since most of the arable land is already in use, productivity gains to meet this growing and predominantly urban population will likely be achieved through sustainably increasing cropping intensity in the country [4]. The agricultural industry is projected to face significant challenges as a result of changing monsoon patterns and rising temperatures, particularly in Pakistan's north, which is already highly vulnerable to climate change. Investment in smart agriculture and IOT based agriculture management will be required to ensure a stable food supply in Pakistan.

Smart farming concept using IOT based modern technology integrated with 5G is the solution to increase the quantity and quality of agriculture products requiring less labor. For increasing number of IOT based application there is need of high-speed connectivity that cannot be provided by 3G/4G. To overcome this issue 5G technology is used ensuring low latency and high bandwidth. The main issue is even though 5G services are available worldwide but it's quite new technology for Pakistan. The development of communication network technology is mainly driven by large mobile operators and micro-electronics companies. However, they focus on exploiting current technologies first (e.g., 3G/4G) and specific IoT protocols because they expect a return on these investments [5]. The introduction of technology is urgently needed since our existing farming methods would not be enough to fulfil the demand for food. Agriculture automation holds a lot of promise for the agriculture sector, which is already transforming the industry.

3. Statement of the problem/Research Gap (Abdullah, 20K-0385)

In most developing countries, smart farming concept was adapted long back and the farmers there are using the technology to grow crops of better quality and quantity which also helps their country's economy. We will be investigating the use of smart farming and its uses in Pakistan so the demand of food can be met easily and Pakistan does not loose foreign exchange for importing food. With Internet of Things and Artificial intelligence, smart farming can boom the yield of the crops and farmers will be able to grow crop in Pakistan which would be of great export quality. Very little work has been done for promoting smart farming in Pakistan, which has eventually lowered the standards of farming in Pakistan with changing climate and natural disasters like floods. There are some limitations too which has to be taken care of like drone usage [2], job security and lack of education among the farmers. We will explore the potential of Internet of Things, 5G technology, Computer vision and Machine learning in farming practices according to the farmer needs in Pakistan and how it can help then with classification of different qualities of a crop, disease detection, pest detection, real time

monitoring of farms, drones, and what hardware and algorithms are best according to Pakistan's environment and needs.

3.1. Market Needs

Agriculture provides employment for 44% of the labor force while 62% of the rural population of Pakistan depend upon this sector for their livelihood [1]. With increasing population, the demand of food supply also increases and factors like climate changes are not helping farmers produce more yield of crops with the old traditional techniques. Our research will assist farmers, particularly those in rural regions, in utilizing technology and the progress of artificial intelligence for their benefit and producing crops that are more in quantity and of higher quality.

4. Requirement Engineering (Abdullah, 20K-0385)

4.1. Stakeholder Identification

The major stakeholder in our research are the farmers in rural areas of Pakistan who are not well known with Artificial intelligence and new 5G technology which they can make use of to increase their productivity and grow crops efficiently with less labor and hard work. Second stake holder are the government agencies who are responsible for agriculture policies and regulations and also give permission for using drones in any area. The common people, consumers, is also a key stakeholder as they would want to know how this smart farming could affect the quality and safety of the food they consume.

4.2. Requirements gathering

To get extra information for our research, we gather more data from various sources to work on our methodology. First, a thorough literature study was done, which included an examination of previous studies and papers on Internet of things and Artificial Intelligence. Then, surveys and questionnaire were distributed to farmers. Data will be collected through a questionnaire filled out by 100 farmers who use old techniques and method of agriculture. Farmers were asked questions which includes:

- How much area is used for cultivation?
- How much time it takes for quality testing manually?
- How much crop is wasted due to pest and diseases infections?
- How much export quality crops are produced?
- How much time it takes to grow certain amount of a specific crop
- Will you leave old methods of farming and use smart farming techniques?

Interviews of farmers particularly in Southern Punjab, who uses some of these smart farming techniques, was done. They were asked questions like the limitations of smart farming, algorithms and their time complexity and challenges of using 4G technology instead of 5G and

its drawbacks. Government publications and academic journals were also used as secondary data sources. Southern region manager of Zong, a telecommunication company, was interviewed to get information about the 5G technology and its release date for commercial use in Pakistan and how 4G's speed can be improved. The combination of these allowed for the collection of a large and diverse data set, offering a thorough knowledge of the usage of AI and IoT in agriculture.

5. Literature Review (Ashraf, 20K-0488)

Pakistan is currently the world's 5th most populous country in the world, and to meet the high demand of food supply, it is necessary for Pakistani farmers especially in rural areas to use advancement of technology and Artificial Intelligence to their benefit and increase the yield and quality of their crops.

This study examined a large number of research topics to explore scientific methods related to smart farming. We have used several sources from various research databases such as Google Scholars and IEEE explore and scientific publishers such as Elsevier, Journal of Electronic Design Engineering, Egyptian Journal of Remote Sensing, etc.

Use of Internet of things (IoT) with Machine Learning and Computer Vision is the future of smart farming. It provides convenience and saves time resulting in more yield of the crops. For e.g. manual methods for grain quality assessment are challenging even for people who are trained to perform this job [6]. Computer vision and Machine Learning can do this in few seconds with almost same or better accuracy.

IoT in smart agriculture

The Internet of Things (IoT) is the network of physical objects that uses sensors, and other technologies for the purpose of connecting and exchanging data with other devices over the internet. In recent years, many use cases of IoT have been explored in the field of agriculture and smart farming. This technology allows all agricultural machinery and equipment to be able to communicate to make irrigation decisions and provide the right fertilizer. [3]. James with other researchers investigated and successfully employed a IoT real-time system to detect and diagnose leaf diseases that hinder crop growth utilizing several satellite photos and sensors positioned in fields using quantitative research. This system assisted in analyzing the data and making decisions, which were then reported back to the farmers using the webserver [7]. The use of sensors and smart systems enables the monitoring of weather factors, fertility status, and the precise amount of fertilizer required for crop growth. IoT based system was used to measure Farm temperature and humidity [3]. Mobile application was created which could control the device from anywhere remotely and monitor the on field activities

5G network on smart farming

Communication and network connection has also advanced in recent years. During the past ten years, 3G or 4G IoT wireless devices were being used for communication. However, the effectiveness of 4G has reduced since the number of devices and quality of information has increased. The fifth-generation (5G) network represents the progression of communication networks by offering extremely fast data transformation speeds. 5G network is faster nearly 100 times as compared to 4G. Farmers using 5G experienced better and smooth communication between their smart devices. However, implementing 5G in rural areas of Pakistan is still a challenge as it needs proper environment for the hardware especially in harsh climate conditions like rainy and dusty. Furthermore, in rural areas, availability of electricity 24/7 is also a challenge as Pakistan is already facing energy crisis. In Pakistan, only one telecommunication company named Zong had tested the 5G technology successfully back in 2021 but it is still not released for common people, or commercial use in Pakistan.

Computer vision

Computer vision is a field of AI that helps computers to extract relevant information from pictures, videos and other visuals. Computer vision has played a vital role in management of smart farm. It is used for classifying crops based on their physical conditions and helps in disease and pest detection. It can be used to detect water level on field for smart irrigation.

Machine Learning

Machine learning is another field of Artificial Intelligence that enables computer to learn and act like a human. The learning algorithms can be categorized into supervised, unsupervised, reinforcement and evolutionary learning [6]. In smart farming, supervised learning is being used most frequently is recent years. In supervised learning, the AI model is trained using labelled data and the model predicts the label of a new unlabeled data. It is being used in classification of healthy and unhealthy crops and identifying different quality levels of the crops. However, the accuracy percentage is still a concern as farmers using old traditional techniques resists using this technology as they feel confident doing this job themselves manually

With the development of intelligent devices that employ computer vision and Artificial Intelligence for agriculture and smart farming, as well as their integration with agricultural machinery and drones, it was determined that there were still certain gaps to be addressed. The most important is the lack of education and awareness of technology among the farmers in rural areas of Pakistan. Usage of UAVs and drones has also its limitations. Furthermore, lack of electricity can also hinder the performance of IoT devices using the new 5G technology while using 4G technology is not smooth and guaranteed to work all the time.

6. Research methodology (Ashraf, 20K-0488)

This research aims to study the impact of smart farming using IoT and AI in Pakistan on the quantity and quality of crops compared to old traditional methods and difference for time it takes to grow the same quantity of crops by both methods

6.1. Hypothesis:

On the basis of problems discussed above and data from previous literature and from sources discussed above in requirements gathering section, this study will be conducted on the following hypothesis:

H1: An increase in smart farming practices in Pakistan will increase the quantity and quality of crops in lesser time.

On the basis of this hypothesis, we will do a quantitative research to observe the impact of AI and IoT in farming as compared to old and conventional methods of agriculture. We will also do qualitative research to gather the data and also observe the impact of using 5G technology instead of 4G in Pakistan especially in the agriculture sector.

6.2. Imaging Setup

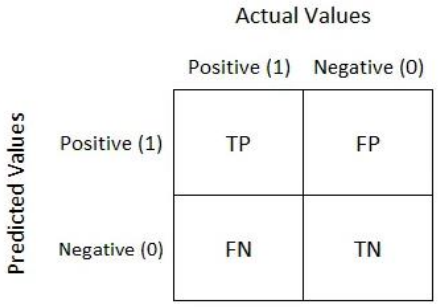
A machine vision system was built using the concepts of computer vision and Python programming. The system consisted of a color camera (Sony, Model-23-2021, Korea) integrated with a lens (3.5–8 mm focal length), and a computer for testing and displaying results. Proper lighting system was also set up so our camera could detect things clearly.

6.3. Classification using Machine Learning

Classification is a Machine Learning method which uses the labelled data to predict the label of a new data. There are various algorithms though which classification can be performed which includes KNeighbors classification, Support Vector Machine(SVM), and Decision Trees. We will be investigating the accuracy and time taken of these 3 algorithms to proposed the best one for use in smart farming.

We trained our model first using a labelled dataset found from Kaggle. This dataset contains pictures of crops infected by disease and pests. Firstly, data cleaning was done by skew correction, image scaling, noise removal and grey scaling of the images. We now, using our imaging setup, took images of crops like wheat and cotton infected by pests and extracted the useful features using computer vision from those images. Features included were major axis length, minor axis length, perimeter, diameter, color and etc. We now present this test data to our KNeighbors classifier model. Same images were presented to SVM and Decision tree classifier also.

The performance of these classifiers were evaluated by forming a confusion matrix and computing the statistical perimeters such as accuracy and precision. Confusion matrix is a performance measurement for machine learning classification which outputs a table with 4 combinations of actual and predicted values



Accuracy is that from both positive and negative classes, how many of them we have predicted correctly. In our case, positive class is pest infected crop and negative class is the healthy crop

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + FN + TN}$$

Precision is that from all the classes we have predicted as positive, how many are actually positive. That is, out of crops infected by pest, how many were correctly labelled as infected crop by our model

$$\textit{Precision} = \frac{TP}{TP + FP}$$

Furthermore, the time taken to classify the infected and uninfected crops using these classification algorithms were also recorded to analyze and compare with the accuracy and time taken by conventional practices of farming and manual testing of crops.

6.4. Classification of crops based on quality

We also used our machine learning models to classify crops based on their quality so they can be separated according to their grades. Images of two different classes of rice including Low-processed grains and High-processed grains were collected using our imaging system which uses computer vision. Our trained models were provided with these images to classify these 2 quality of grains. The models were able to classify the grains and the accuracy and time taken was recorded.

6.5. Testing with 4G technology

Our imaging system was also integrated on a drone, and it was used to fly on an agricultural field of 8 acres. The drone was able to collect data of the crops to send it to our Machine Learning model. Time taken in covering and scanning the whole farm was recorded. The data between our devices was shared using 4G technology. The numbers of times data transfer fails and number of times the connection was broken or disrupted was also recorded.

7. Findings and analysis (Shahzaib, 20K-1067)

In the light of discussion above, our study will analyze the impact of using smart farming in Pakistan to increase the yield and quality of crops more efficiently and with less efforts in little time.

Accuracy of classification models:
The results of 3 classification models we used to classify crops with pest infection were analyzed. Using their confusion matrix, the accuracy and precision calculated using the test data is shown in Table 1

Classification Algorithms	Precision (%)	Accuracy (%)	Time(minutes)
Knearest neighbors	88	87	7
Support Vector Machine	84	89	8.5
Decision Trees	75	79	9

Table 1. Performance of classification models for pest detection

As discussed earlier, data was also collected by questionnaire given to 100 farmed of southern Punjab. Questionnaire mainly consisted of questions that were aimed to identify the time taken and how much effort is required by farmers to grow crops and manually test the quality. A total of 100 responses were obtained for analysis in this study. All responses were fully answered out of 100.
From the answers, it was calculated, using SPSS software, that it takes 20 minutes on average for a farmer to manually separate pest or disease infected crops from other crops with 75% accuracy, while our classification models were able to identify them in 8.2 minutes on average with 85% accuracy. To identify the best performing algorithm, mean of precision and accuracy was calculated which shows that Knearest neighbors algorithm has the highest mean and is the best algorithm to use for pest or disease detection.

Accuracy of classification models based on quality:
The results of 3 classification models we used to classify crops based on their quality to separate them in different grades were also examined. Using their confusion matrix, the accuracy and precision calculated using the test data is shown in Table 2.

Classification Algorithms	Precision (%)	Accuracy (%)	Time(minutes)
Knearest neighbors	49	78	10.5
Support Vector Machine	78	87	7.5
Decision Trees	77	79	6.5

Table 2. Performance of classification models for qualitative classification

From the questionnaire, it was estimated that it takes farmers around 40 minutes with 66% accuracy to classify crops based on their quality for grade separating of crops while our models were able to achieve them in 8.3 minutes with 81% accuracy. Again to find out the best performing algorithm, mean of precision and accuracy was calculated which shows that Support Vector Machine has the highest mean and is the best algorithm to use for qualitative classification of crops.

Performance of 4G

4G technology was used by the drone to send and receive data to our models hosted on our PC locally. The drone scanned the whole farm 10 times and each time the number of times connection was disturbed and the amount of time it took to cover the farm was also recorded which is presented in table 3.

Test fly of drone	Connection disrupted	Time to scan farm(minutes)
1	2	3
2	3	2
3	5	2.5
4	1	3.2
5	0	2.6
6	2	2.8
7	1	3.1
8	2	2.6
9	1	2.6
10	0	2.4

Table 3. 4G performance on drone

The results show that on average connection was disturbed 1.7 times while it took around 2.68 minutes to cover the whole farm by the drone and send data to be used by over Machine Learning Models. As discussed earlier in the requirements gathering section,

Southern regional manager of Zong, was interviewed to get information about the 5G technology in Pakistan. It helped to gather in-depth insights about the 5G technology in Pakistan. Due to hardware being costly, most telecommunication networks company are currently only looking to exploit the potential of 3G and 4G while testing their 5G technology so it can be released for commercial use whenever the issues are solved. Hence, no major advancement have been made in recent time to release 5G technology in Pakistan which can be used for agriculture.

8. Project Management (Shahzaib, 20K-1067)

8.1. Platform / Technology used:

This research aims to explore the use of smart farming in Pakistan to ease the work of farmers and help them work effectively using the IoT and Artificial Intelligence. For designing the Machine Learning models, Jupyter notebook was used on localhost, to manage different algorithms of classification technique. The models were written in Python Programming Language. To analyze the data collected from questionnaire filled by the farmers, SPSS software was used. It is a statistical software developed by IBM for data management. It was used to explore and analyze the responses of the questionnaire.
To organize the research and literature review, Mendeley was used to take notes and save the important point from the research papers and journals

8.2. Time scheduling

The Gantt chart below in Fig 3 shows how the research was managed and carried out from start till finish.

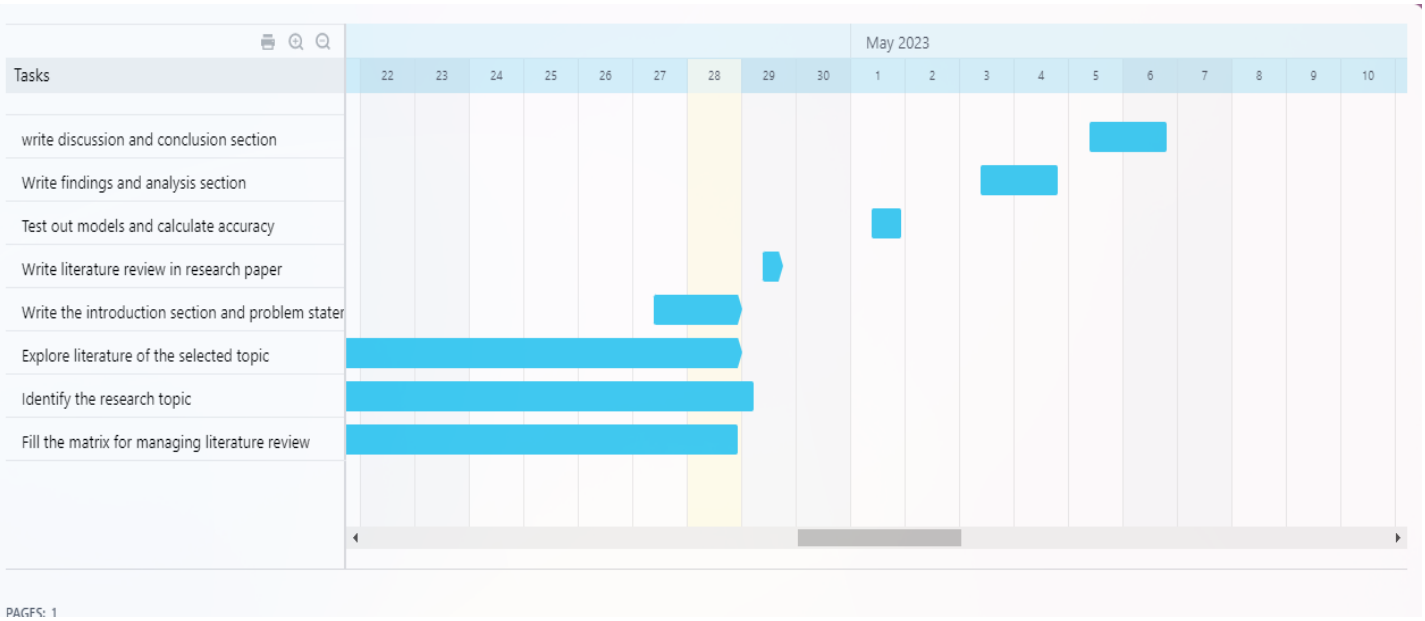


Fig 3. Gantt char

9. Significance of the Project (Shaikh, 20K-0319)

Our research aims to promote smart farming concepts in Pakistan to increase the yield and quality of crops with much less efforts for farming which will also benefit the GDP of Pakistan. As discussed in the findings and analysis section above, it was found that Computer vision can be used effectively to extract the feature of images which is then used by Machine Learning models for disease and pest detection, and qualitative classification of the crops. It can also be used for smart irrigation where the soil moisture and water level on the farm can be detected and when needed, it can automatically irrigate a certain area of the land. This will save a lot of time and effort of the farmers. However, this study also shows that using 4G technology is a bottleneck in this effort of promoting smart farming and 5G technology will still take some time to be introduced in Pakistan and for commercial use. In developed countries, 5G technology is being used which gives much better results as the connection is smooth with no disruptions which means no data is missed by the sensors and IoT devices and all that data is used by Artificial Intelligence to predict much accurate results.

10. Limitations (Shaikh, 20K-0319)

There were some limitations while conducting the research, which are as follows:

- The sample size of the data was small because of time constraint. A greater sample size would have resulted in more accurate results.
- The testing of drone was only done in parts of Southern Punjab. It is not known how it would perform in other parts or regions of Pakistan with harsh climate.
- The potential of 5G in agriculture in Pakistan could not be tested because of lack of availability of the technology in Pakistan.
- The data collected from farmers by a questionnaire may subject to potential deviations in the result as many farmers are not well educated and might have not understood certain questions completely.

11. Conclusion (Jodat, 20K-0155)

In conclusion, this research aimed to examine the impact of smart farming in agriculture sector of Pakistan. Overall, the research supports the hypothesis that use of smart farming methods in Pakistan will increase the yield and quality of the crops in much lesser time and more efficiently. The current work highlighted the significance of smart farming for raising agricultural production in order to help close the gap between supply and demand for food. IoT is regarded as the backbone of smart agriculture technology since it links all parts of intelligent systems used in both agricultural and other applications. Combining Internet of things (IoT) with the power of AI raises the amount of impact IoT alone has on agriculture. This work reviewed the integration of IoT with Artificial Intelligence and how it can help

farmers with smart irrigation, pest and disease detection using Machine Learning, farm monitoring, and qualitative classification of crops. Artificial Intelligence makes all these tasks done in much lesser time compared to manual work or old traditional techniques.

12. Future Scope (Jodat, 20K-0155)

The proposed solution has been found to be more accurate and less time consuming. Farmers would be able to spend less time and get more precise results of their work. The system can be implemented in urban gardens, rural farms, and greenhouses. The future scope of this work extends to a much larger concept as all these features will have to be included in a mobile application and integration of 5G with that app in Pakistan will be a challenge as not a lot of work has been done on 5G and its implementation in Pakistan. In the future precise agriculture concept can be implemented with Artificial intelligence where systems can decide type of soil, crop density, soil health and weather patterns on its own. Farmers can make more informed decisions about when and where to plant crops, how much water and fertilizer to use, and when to harvest the crops. Intruder alert system can also be merged with the system in the future when the system will alarm the farmer about any potential thief or wild animal attack on the farm. Moreover, as it was analyzed from our questionnaire that most of the farmers were not ready to switch to new technology and leave their old conventional methods of farming, hence work has to be done on how to convince and educate more farmers to start using smart farming concepts to increase their productivity. Summing up all, Artificial intelligence has been instrumental in making significant advances in agriculture, where the system adjusts to crop requirements based on real-time data inputs and requirements. It provides a feasible solution to farmers to grow crops more efficiently with little or no manual work.

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