INFORMATION COMMUNICATION TECHNOLOGIES FOR IRRIGATION MANAGEMENT SYSTEMS: AN EMPIRICAL INVESTIGATION

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ABSTRACT

With the advancement in information communication technology ICT and its introduction in the field of agriculture, the community has to shift from conventional ways to technology oriented solutions. In this paper, a mapping study research technique was adopted to identify evidences related to irrigation systems developed for efficient use of water. The study findings showed that proposed solutions were quite advance, expensive and were largely used by agriculture scientist rather than farmers. Therefore, simple and efficient ICT tools were required to address farmers' requirements and adoption of such solutions to be evaluated in real environments. In case of Pakistan, situation was not very different due to low digital literacy rate. Therefore, proposed smart solutions for irrigation require thorough evaluation by farmers.

Key words: Irrigation systems, Water management, Information communication technology, Precision agriculture.

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INTRODUCTION

Agriculture is a very old profession that can develop prosperous society (Posthumus *et al.*, 2013). It is widely adopted profession across the world and a large number of labor is associated with this profession. It is backbone of economy of many developed and developing countries. In the ancient times, agriculture was a simple profession, required fewer resources and these resources were simple to manage and operate. In this profession, induction of modern information communication technology ICT has reformed it and its modern form is known as e-agriculture. The concept of e-agriculture was introduced in World Summit on Information Society in 2003 with the objective of improving the living standard of farmers and to produce safe and healthy food with least input resources (WSIS-03/GENEVA, 2003). Therefore, ICT has a potential to efficiently contribute in the development of agriculture community (Gupta *et al.*, 2012).

ICT based agricultural systems such as Agricultural Decision Support System, Agricultural Management Systems, Agricultural Expert Systems and Agricultural Information Systems have been developed to support farmers in all agricultural operations like ploughing the field, seeding, spraying, irrigation, harvesting, transportation and marketing. These systems are very useful. However, there are obstacles in adoption of these systems. They further reported that the farmers who adopted ICT in agriculture were getting more benefits than those using the traditional system (Batte and Arnholt 2003). Moreover, farm managers using agricultural decision support systems were getting more benefits compared to those who were not using such systems (Nuthall, 2004). The biggest obstacle in adoption of such systems is illiteracy. The literacy rate is quite low in farmers' community. Therefore, they are reluctant in using ICT tools that could facilitate them in agricultural activities (Wen, 2010).

Agricultural operations consume different types of resources and most of these resources are wasted by improper management techniques and substandard practices employed by farmers (Adikari, 2010). Along with resources used for agriculture, water is used in huge quantity during irrigation that makes its management very important. Irrigation is an important agricultural operation which is required by all types of crops. In literature, various irrigation management systems have been introduced based on ICT. Many of these systems are a combination of software and hardware technologies. The objective of these systems is to make the efficient use of water and to make the irrigation operation as simple as possible (Silva and Vuran, 2010), (Lima *et. al.*, 2010), (Melton *et al.*, 2012), (Car *et al.*, 2012) and (Li *et al.*, 2013).

This research provides an insight into different types of irrigation systems being discussed in literature and analyzed them to evaluate their usability by farmers.

MATERIALS AND METHODS

This research was a part of mapping study conducted on e-agriculture. Mapping study, also called scoping study was conducted on a broad topic that made

it different from systematic literature review (SLR) which was another form of literature review that covered literature on a narrow and focused topic (Kitchenham and Charters, 2007). While conducting mapping study, various areas of agriculture were identified, where ICT technologies were proposed. An important area among these was irrigation system to facilitate farmers in water management. This study was particularly focused on irrigation systems being proposed by e-agriculture research community.

The overarching research question was designed to conduct this research is defined as:

What irrigation systems are being developed to support farmers in water management?

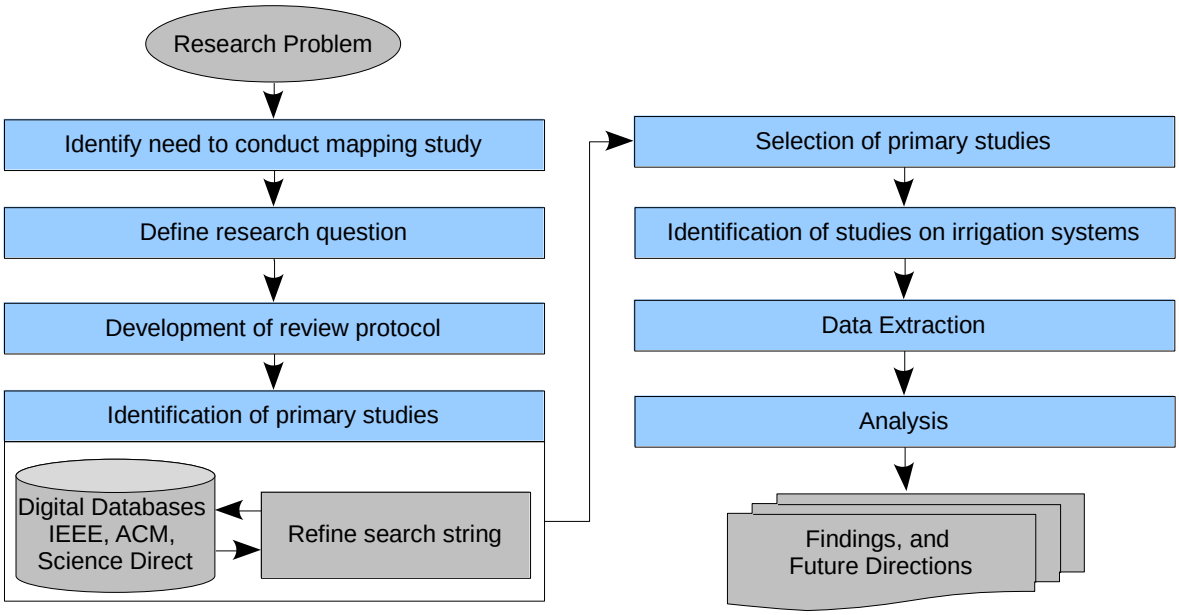

Fig. 1: Research Design

To answer research question, we conducted a mapping study following the process given in Figure 1. To develop review protocol, guidelines provided by (Kitchenham and Charters, 2007) were employed. To identify relevant studies, a search string was formed through prototyping. The search string used was:

E-agriculture **OR** E agriculture OR Information system for farmer **OR** decision support system for agriculture **OR** Decision Support System for Farmer

The primary studies were identified by using search string in three digital databases that included Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM) and Science Direct. The time period used to identify studies was from 2000 to 2013. A total of 791 studies were identified from selected databases. The search in these databases was made by using their advanced web interfaces. To maintain context and relevance of studies, automatic data extraction tools were avoided. These databases were used because of their high standard and paper quality that were directly linked to threats to validity and quality of dataset.

After applying inclusion/exclusion criteria as per review protocol 213 relevant studies were selected. To identify studies on irrigation systems, search focus was narrowed down and 13 primary studies were selected by scanning full text of 213 primary studies. Data was extracted and coded in spread sheets for analysis.

RESULTS AND DISCUSSION

The data was extracted from primary studies for analysis which included type and year of publication, agricultural components addressed, and location where field work was carried out and the details about the vegetation monitored. Studies carried out by (Shaffer *et al.*, 2004), (Zhong- xiao and Yimit, 2009), (Silva and Vuran, 2010), (Car *et al.*, 2012), and (Andriyas and McKee, 2013) applied their experiments on corn fields, grapes, alfalfa, barley, and on arid zone crops. Various studies had conducted field work to evaluate their proposed solutions. In this regard, most of the studies were conducted in USA by (Shaffer *et al*., 2004), (Silva and Vuran, 2010), (Melton *et al.*, 2012), and (Andriyas and McKee, 2013). (Sha and Zhang, 2007), (Qingyuan *et al.*, 2007) and (Zhong-xiao and Yimit, 2009) who did evaluation in different areas in China. (Car *et al.*, 2012) and (Li *et al.*, 2013) conducted field study in Australia whereas field study by (Bazzani, 2005) was from Italy. Apart from two studies (Lima *et al.*, 2010) and (Patel *et*

al., 2012), all studies reported the location of their experiment.

These studies included various agricultural components in their solutions. Studies carried out by (Shaffer *et al.,* 2004), (Bazzani, 2005), (Sha and Zhang, 2007) and (Qingyuan *et al.,* 2007) proposed simulation models that provided an integrated solution by involving irrigation and fertilizers management systems. In studies conducted by (Silva and Vuran, 2010), (Lima *et. Al.,* 2010) and (Melton *et al.,* 2012) sensor networks were used to support various water management activities. The solution proposed by (Lima *et al.,* 2010) provided a simulation environment where various sensors could be deployed for irrigation. Mobile and cloud based solutions were proposed by (Car *et al.,* 2012) and (Li *et al.,* 2013) whereas water demand forecasting models were discussed in studies carried out by (Chatzikostas *et al.,* 2013) and (Andriyas and McKee, 2013).

The primary studies were further analysed to identify the type of system being proposed, technology that included development and infrastructure, intended users of these systems and evaluations carried out for these systems.

Since all systems were developed to support agriculturist in making decisions therefore, they all fall under the category of decision support systems. The system type was defined according to the functionality described by the study. The intended users were identified by focusing on the nature of the developed system and the evaluation criteria used by various studies.

From development perspective, the systems discussed in these studies fall under the category of simulations. The studies carried out by (Patel *et al.,* 2012) and (Andriyas and McKee, 2013) were algorithm centered and evaluation of these was not reported. Studies that made use of web and mobile applications included (Car *et al.,* 2012) and (Li *et al.,* 2013). The evaluation of study by (Car *et al.,* 2012) was carried out for nine months with irrigators. The participants were interviewed to evaluate the usability of the system. This was the only study found where users from field work were directly involved and engaged for a long time period. In another study carried out by (Li *et al.,* 2013) data was collected daily for two years for evaluation of system.

Different development technologies were used to propose a variety of solutions that were implemented to provide the proof of the concept. The development technologies used included .Net framework, Android, C++, FORTRAN and Python. Apart from development technologies, integrated sensor networks, geographical information system GIS, global positioning system GPS, remote sensing, satellite imagery and irrigation domain specific models were also incorporated into their solutions.

The range of proposed solutions covered irrigation information dissemination systems to automatic irrigators. These automatic irrigators sense the water requirement and start irrigation automatically. The irrigation system characteristics defined in studies also varied on the type of problem. Studies carried out by (Patel *et al.,* 2012) and (Car *et al.,* 2012) discussed irrigation scheduling whereas (Lima *et al.,* 2010) focused on humidity level control.

These proposed systems provided an efficient way of irrigation however real concern is their cost and adoption. Normally, the cost of water was not high. While selecting any irrigation system, farmers had to concentrate on cost associated with these systems. Moreover, if the cost of these systems was higher than the water it consumes then such systems will not be considered economical especially for small land owners. Furthermore, these systems were complex and required technical knowledge and expertise. Only one study was found which involved irrigators from fields by developing mobile application for water management (Car *et al.,* 2012). Another study made their work publically available, though the issues of adoption were same as for others (Melton *et al.,* 2012).

Conclusion: In this paper, state- of- the- art research was discussed on the area of e-agriculture with special emphasis on irrigation systems and use of ICT Tools. The research discussed is largely conducted in developed countries where the proposed solutions are experimental and not fully tested in real environments by agricultural community. However, these experiments have made use of data provided by government and private sector. Therefore, it is easy to analyze data in broad perspective. However, the real challenge comes for the developing countries where ICT reforms need to be incorporated at government and organizational level. Pakistan like many other developing countries has a traditional irrigation system which needs modernization. One of the biggest problems with its irrigation system is its reliance on conventional technologies, and supply based irrigation water management. The study has implications for Pakistan to modernize its irrigation infrastructure using modern technologies and change it from supply based to demand based management system.

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