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Long-range real-time monitoring strategy for Precision Irrigation in urban and rural farming in society 5.0

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ABSTRACT

Urbanization is the biggest challenge as by 2050 it is projected that more the 60% of the world population will inhabit cities. This will present stress to the available city's resources like transportation, health system, economy including agricultural products importantly safe food supply. For these concerns, advanced solutions are required with a human-centric approach for sustain- able development. Society 5.0, smart cities, and urban agriculture are the latest concepts with the objective of sustainable development. Most of the article on smart cities fails to put focus on different aspects, objectives, and importance of urban agriculture. This article disclosed various aspects and objectives of Society 5.0, a smart city, and the concept and importance of urban agriculture. Agriculture other than facing the challenge of huge urbanization also faces inefficient utilization of scarce resources with inefficient agricultural practices particularly irrigation water. The present article discloses the importance of efficient agricultural resource utilization particularly irrigation water and provides a design for Precision Irrigation for field monitoring. The discussed design offers a Long Range, Real-Time, and scalable solution for field irrigation requirement monitoring based on soil and weather conditions and addresses most of the challenges facing in-field monitoring such as range coverage of sensor nodes and scalability, data recording, power, and cost.

1. Introduction

Industry 4.0, Industry or Society 5.0, smart city, and urban farming are the main theme of this article. Industry 4.0 was an initiative by the German government in 2011 with the theme of "smart manufacturing for the future (Demir et al., 2019; Paschek et al., 2019; Skobelev and Borovik, 2017) by offering advantages such as process automation, improved efficiency and productivity, scalability, and increased profitability (Paschek et al., 2019). A few of the key and trending technologies for Industry 4.0 are IoT, AI, 3D printing, and augmented reality (Demir et al., 2019). Industry 5.0, the new paradigm developing in parallel to Industry 4.0, aims to be more human-centric in comparison to Industry 4.0 by providing a connection between innovation and technological policies for suitable ecosystem and sustainable development. There exist some other concepts similar to Industry 5.0 such as "implement ability" and human-centric design (HCD) and design thinking (DT). According to "implement ability" innovation should add value to life otherwise it cannot be recognized as innovation. Under HCD potential users for the innovation is the main driving force in decision making. DT helps in understanding the innovation process and breaks the rule of rewriting new ones. For innovation, three types of users are identified namely (Carayannis et al., 2021)

1. Primary user having frequent hands on to the system,
2. Secondary user which uses system through intermediator and,
3. Tertiary users get affected by the introduction of a system or influences the system.

Industry 5.0 and society 5.0 are interchangeably used. Industry 4.0 aims towards digitalization and automation of manufacturing. Whereas Industry 5.0 or society 5.0 considers the integration of human factors i.e. workers into the industry. Industry 5.0 is also determined as society 5.0 with the human-centric approach for economic progress and social problem resolution (Ávila-Gutiérrez et al., 2021; Fukuyama, 2018); by integrating cyberspace with the physical world (Ávila-Gutiérrez et al., 2021).

The concept of smart cities is often considered as an outcome of technology but it's an integrated, multidisciplinary holistic approach

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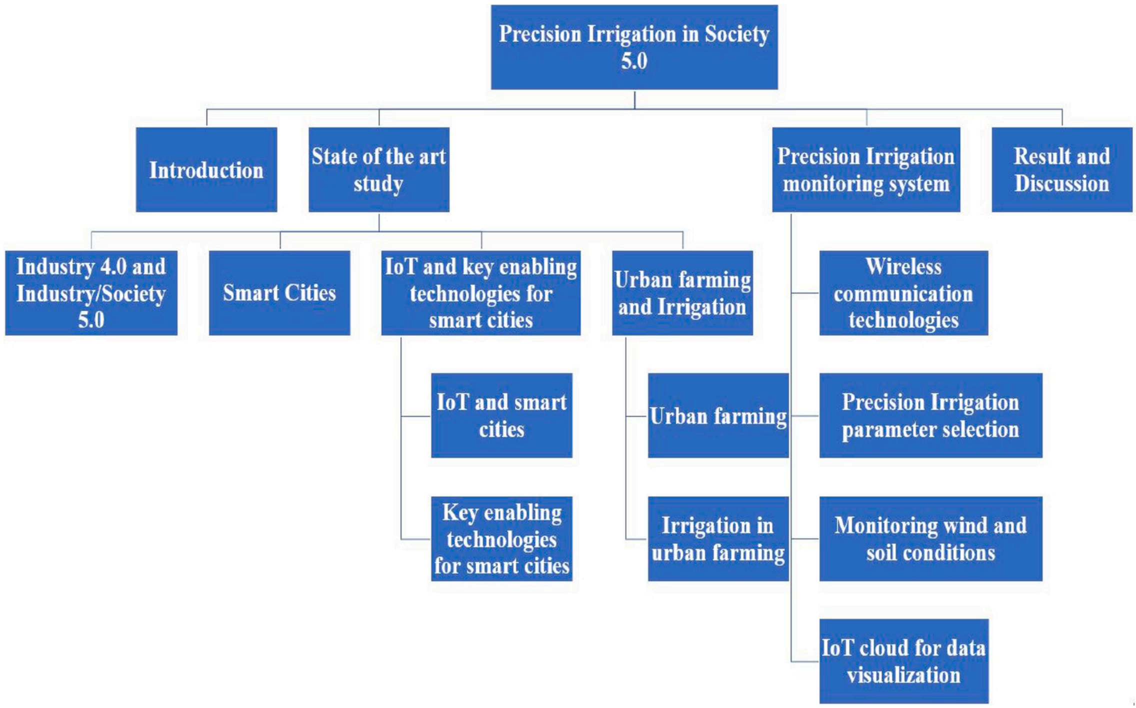

Fig. 1. Structuring of paper into different sections and subsections.

with the objective of sustainable environment, quality of life, and cost of living. (Gharaibeh et al., 2017; Zubizarreta et al., 2016). The concept of smart cities considered environment sustainability as one of its prime objectives (Ahvenniemi et al., 2017); superior social life, improved quality of life, less waste, and good efficiency are a few of the other sustainable goals of the smart city (Zubizarreta et al., 2016).

The smart city is a broad and current topic of interest using communication and technology to improve living conditions in cities. As predicted about 60% to 70% of the world population is expected to settle in cities by 2050, the future cities need smart solutions to mobility, healthcare, civil infrastructure to make life in cities sustainable, livable and feasible (Al-Smadi et al., 2019; Alavi et al., 2018; Ahvenniemi et al., 2017). Cities also have a crucial role in combatting climatic changes by deploying intelligent technological solutions (Ahvenniemi et al., 2017) and many of the cities are being ranked based on their social, economic, and environmental conditions (Ben Letaifa, 2015).

The urbanization and migration towards cities (Ahvenniemi et al., 2017; Orsini et al., 2013) have resulted in the loss of agricultural land due to which there is increased stress on the agriculture system (Martin and Molin, 2019). Amongst the other resources, sustainability and food are also important aspects of Society 5.0 and the smart city which is quite neglected in various works of literature related to smart cities. To provide food and reduce the load on agriculture, urban facing or agriculture such as vertical farming and hydroponic farming are identified as a propitious solution. Another aspect of urban farming is to provide locally grown food to citizens and reduce transportation (Martin and Molin, 2019). The continuous increase in the population in cities is leading towards massive problems related to unemployment, transportation, food supply, and protection of the environment. With the development of cities and to handle the problems related to food and the environment, a new type of agriculture scenario is developing i.e., “urban agriculture”. Urban agriculture includes aquaculture, livestock, and plants newly developed concept of agriculture i.e., “urban agriculture” applies to both rural and urban areas (Bon et al., 2010).

Technology plays an important and indispensable role in the transformation and advancement of Industry 5.0/

Society 5.0. and smart city. Among various technologies, IoT and ICT with Big data are the technologies considered as an integral part of the 5.0 paradigm and smart city. Out of the four pillars of a smart city, one is the physical infrastructure which mentions the role of technology in a smart city (Mohanty et al., 2016). IoT is the expanded application of the internet whose aim is to achieve real-time connectivity and communication between humans, machines, and things and is expected to be an $11.03 billion market by 2026 (Wang et al., 2021). Although monitoring remote monitoring of sensors and actuator control was in practice for many years but the concept of IoT has integrated all such concepts into a common framework and has grabbed the focus of industry, society, and academicians to enhance day-to-day activities. The three visions namely Things oriented, semantics-oriented, and internet-oriented combined and gets converges to IoT (Ibarra-Esquer et al., 2017). In agriculture, IoT plays an important role in the monitoring of various vital parameters. Mapping, weed detection, seed planting, application of fertilizers and pesticides, livestock management crop disease and pest management, aquaculture, and Precision Irrigation are some of the major areas where agriculture has been benefitted from IoT.

This article presents the various technological aspect, themes and objectives, and applications of Industry 4.0, Industry or Society 5.0, smart city, All the technological developments collectively focus and aims to achieve the goal of suitable development. The various research questions the author explored and provide the solution by the development of a system for Precision Irrigation monitoring are

RQ1: What are the different aspects of Society 5.0 and smart city

RQ2: Role, contribution, and key enabling technologies in Society 5.0 and smart city

RQ3: What is “Urban Farming” and its role in the present era of technology and urbanization RQ4: Role of urban farming in achieving the objectives of society 5.0 and smart city

RQ5: Requirement and Importance of Precision irrigation

RQ5: What are the various technological advancements available for the modernization of agriculture

When the literature is searched using various keywords for Industry 4.0, Industry or Society 5.0, smart city, some- way it fails to address the most important aspect of sustainable development i.e., agriculture and connected activities. This is becoming a more and more prominent topic

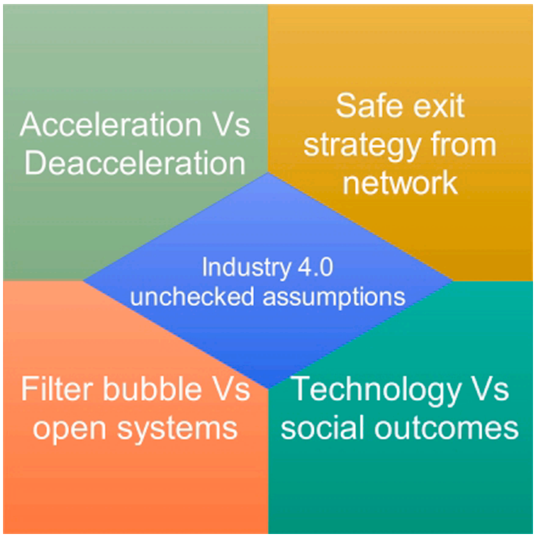

Fig. 2. Assumption left unchecked in industry 4.0 (Özdemir and Hekim, 2018).

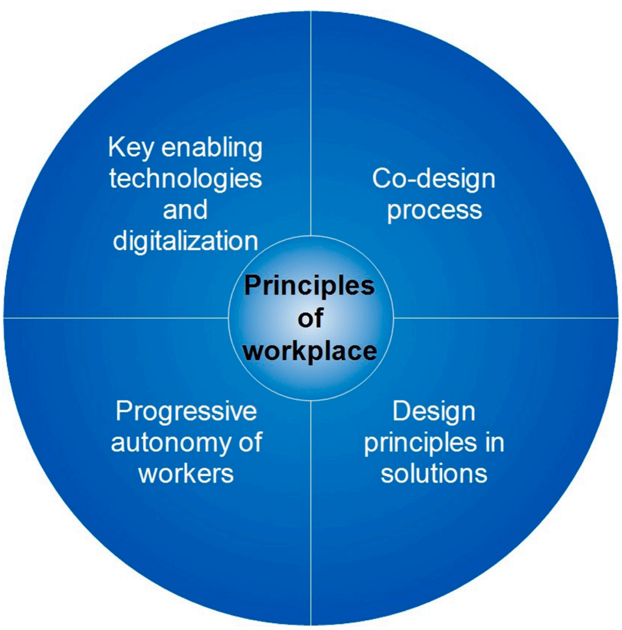

Fig. 3. Characteristics of the workplace of workers (Ávila-Gutiérrez et al., 2021).

due to huge urbanization with the development of cities, increased population, increased stress on agriculture to supply food to the increased population, decrease in agricultural land, and conventional practices utilizing scarce resources inefficiently such as irrigation water. Irrigation is an important activity in agriculture and uses about 70% of the freshwater for irrigation and due to inefficient irrigation practices like flood irrigation most common in India result in wastage of freshwater resource which also results in a change of soil properties, pollutes water resources, washed away soil nutrients (Longo et al., 2020; Zhang et al., 2018). Most of the irrigation monitoring solutions available are for the short range. The challenges faced by agriculture due to new lifestyle, lack of long range predictive IoT based irrigation monitoring and control solutions, aiding the farmers to take the correct decision at the appropriate time and the inefficient conventional practices in agriculture motivates the authors to explore the possibilities available solution and supportive infringement of technology in field agriculture to propose a feasible, workable and easy to use solution for Precision Irrigation. The authors provide the design of long range remote field monitoring precision agriculture using the long-range scalable wireless technology based on soil and weather conditions. In the end, the results obtained by testing the proposed system and the challenge sin Urban farming are presented.

Literature survey provided the important aspect, applications, objectives and themes, and available technologies for Industry 4.0, Industry or Society 5.0, smart cities. This provides the information that the various aspects of urban farming and are missing from the smart city concept and applications. The author based on the literature survey and the importance of agriculture proposed the new thread in smart cities i.e., urban farming. Further the various important parameters affecting the agriculture production are identified and based on that the system is proposed for Precision Irrigation monitoring.

The paper is organized into various sections to understand in detail the history and present developments in Industry 4.0, Industry or Society 5.0, the smart city, and presented the results of the proposed system as shown in Fig. 1.

2. State of the art study

The concept related to Industry 4.0, Industry/Society 5.0, and smart city with importance and requirement of Urban in the present era of technology and urbanization is presented. The understanding is required and is of much importance to understand the requirements and direction for sustainable development.

2.1. Industry 4.0 and Industry 5.0

Industry 4.0 is abetted by IoT and AI techniques that emerged nearby 2000 and continuing to date. From 2016 new concept of Industry 5.0 has emerged. Industry 4.0 is characterized by the deployment of technologies such as 3D printing, IoT, electric vehicles, AI, ML. Industry 5.0 focuses on man–machine interaction and thus allowing the scope for personalized products and services. Industry 5.0 is mainly characterized by robots, augmented reality, IoT, brain-machine interface, and is human-centric. Apart from highlighting the various characteristics of Industry 5.0 and its focus areas, the study in (Aslam et al., 2020) has also put focus on problems faced by organizations in the implementation of the latest innovation like Industry 4.0 or Industry 5.0. To aid the organization in implementing the innovation article has proposed the "Absolute innovation management" AIM framework. The proposed framework aims to make the innovation understandable, implementable, and an everyday routine for the organization. The proposed innovation framework is significant in terms of

1. Making innovation implementation clear, comprehensive, and practical.
2. Making innovation implementation in the organization rapid and creating a sense of responsibility with employees.
3. Making innovation management a part of an organization's routine activity rather than managing it as a standalone activity.
4. Synergizing design thinking and cooperate strategy for maximum benefit.
5. Attaching innovation to cooperate strategy and reducing the side effects due to partial understanding and discontinuities in innovation

Industry 4.0 is backed by IoT mainly builds on internet connectivity, embedded sensors in objects or things, and the concept of ASI and ML. Although Industry 4.0 is still got to be standardized, the new concept of Industry 5.0 is evolving in parallel characterized with empowering the people by allowing them to express themselves through human–machine interaction (Aslam et al., 2020), safe exit in case of security threat from the hyperconnected digital world, emphasis on acceleration and deacceleration base on returns and involving social science and humanities as part of technology (Özdemir and Hekim, 2018), human-

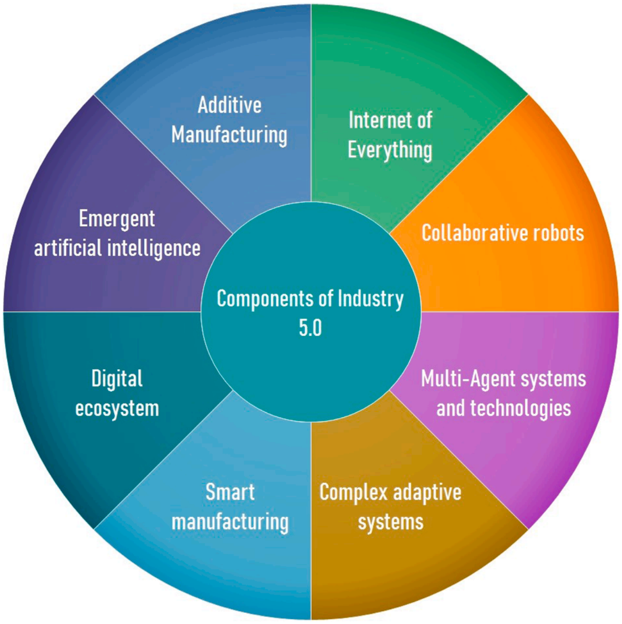

Fig. 4. Various components of Industry 5.0 (Haleem and Javaid, 2019).

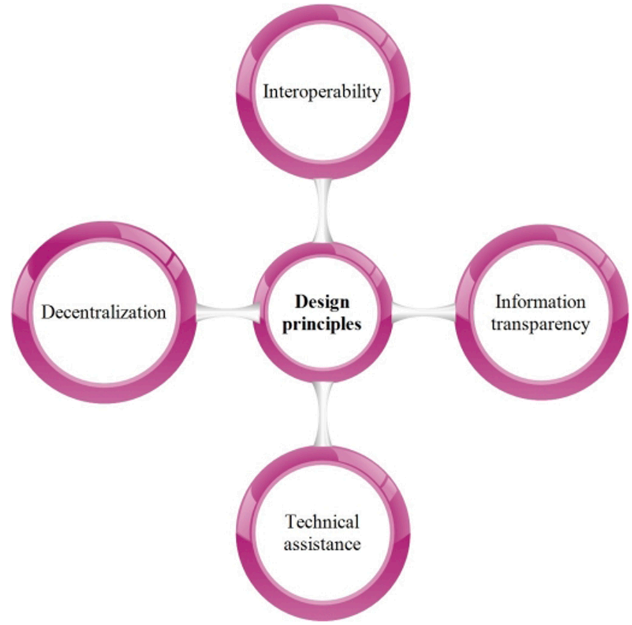

Fig. 6. Design principles of Industry 4.0 (Paschek et al., 2019).

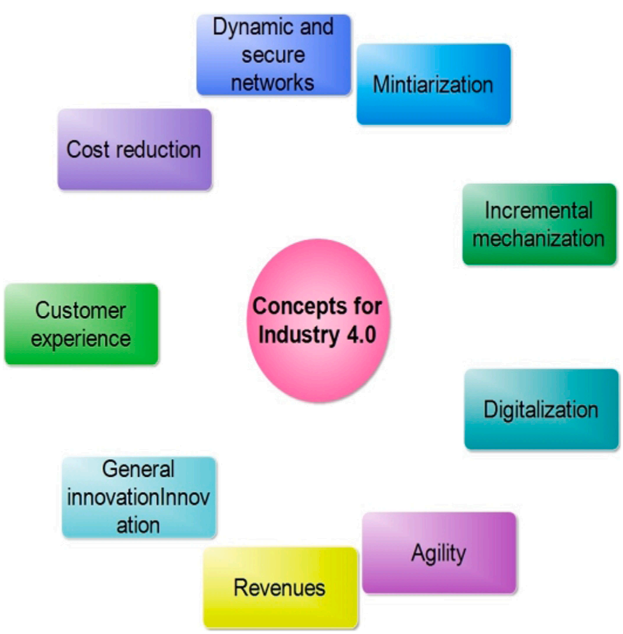

Fig. 5. Encompassed concepts of Industry 4.0 (Paschek et al., 2019).

centric solutions for sustainable development (Carayannis et al., 2021), augmented reality with human and machines working together in close interaction (Longo et al., 2020).

A few of the applications of Industry 4.0 are smart factories, smart retail, services, medicines, and life sciences. Innovation in Industry 4.0 has provided solutions in many areas but has also overlooked certain assumptions as highlighted in Fig. 2 summarized from (Özdemir and Hekim, 2018).

In case of a security breach safe exit from the network is required from network, acceleration, and deacceleration based on return needs to be part of innovation and innovation mandatorily be connected to societal outcomes. Industry is an enhancement to industry 4.0 with IoT, safe exit from connected network acceleration and brakes to innovation and global governance for policies to technology as main elements (Özdemir and Hekim, 2018; Kiran et al., 2020).

As per the article (Ávila-Gutiérrez et al., 2021), Industry 5.0 utilizes similar technologies as in Industry 4.0 such as AI, ML, IoT robots, cloud computing, big data, etc. but also considers the social aspect such as poverty, health, gender equality, prosperity, and profitability. In this sense Industry 4.0, is limited in scope focusing mainly on cost reduction and systematic and structured production approaches. The main principles of Industry 5.0 are depicted in Fig. 3, based on the proposed framework DfAW 5.0 for the workplace of workers in (Ávila-Gutiérrez et al., 2021).

The approach and concept of Industry 5.0 have been discussed for smart manufacturing in (Longo et al., 2020); for the wind turbines, and for orthopedic in (Haleem and Javaid, 2019). In Industry 5.0 the role of human intelligence is improved to supervisory there the is responsible for high-level decisions assisted by the human–machine interface (Ávila-Gutiérrez et al., 2021). Industry 5.0 is showing a significant impact on manufacturing, medical, and civil society. It aims to improve the alliance of smart systems with humans by deploying both the highly precise automation systems and the critical thinking of humans. The revolution of Industry 5.0 looks towards highly personalized products or services in the medical and orthopedic fields. The research article has provided the various component of industry 5.0 as provided in Fig. 4.

Industry 4.0 was an initiative by the German government in 2011 with the theme of "smart manufacturing for the future (Demir et al., 2019; Paschek et al., 2019; Skobelev and Borovik, 2017) by offering advantages such as process automation, improved efficiency and productivity, scalability, and increased profitability (Paschek et al., 2019). A few of the key and trending technologies for Industry 4.0 are IoT, AI, 3D printing, and augmented reality (Demir et al., 2019). Fourth industrial revolution stands on 8 concepts and 4 design principles as mentioned in (Paschek et al., 2019) and depicted in Figs. 5 and 6 respectively. For the modification of organizations towards Industry 4.0 horizontal integration i.e. between organization and business, vertical integration i.e. collaboration amongst various levels in the organization, and end-to-end engineering i.e. customer-oriented product/service design and development needs to be considered (Paschek et al., 2019). It is always quite difficult to achieve optimization in multi-criteria-based processes such as in Industry 4.0. The industrial fourth revolution by considering the trade-off between the various challenges has provided many benefits to organizations such as efficiency, customer experience,

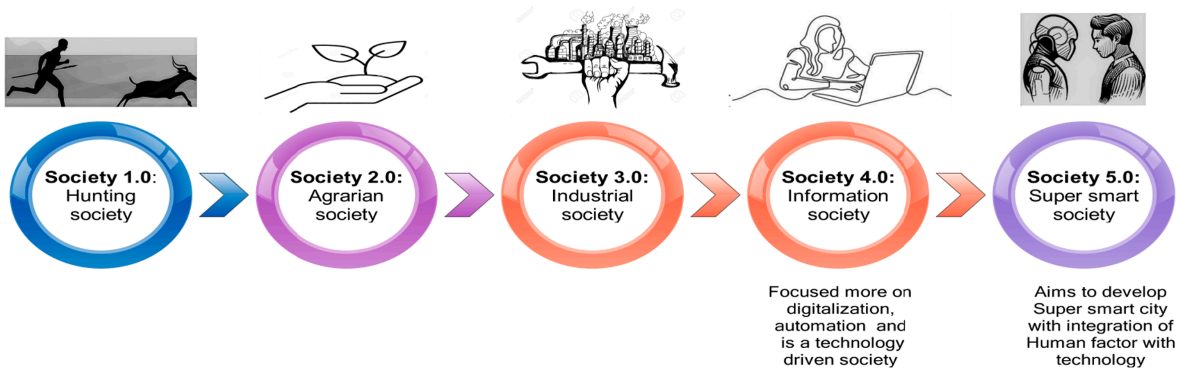

Fig. 7. Evolution of society from Society 1.0 to Society 5.0 (Fukuyama, 2018).

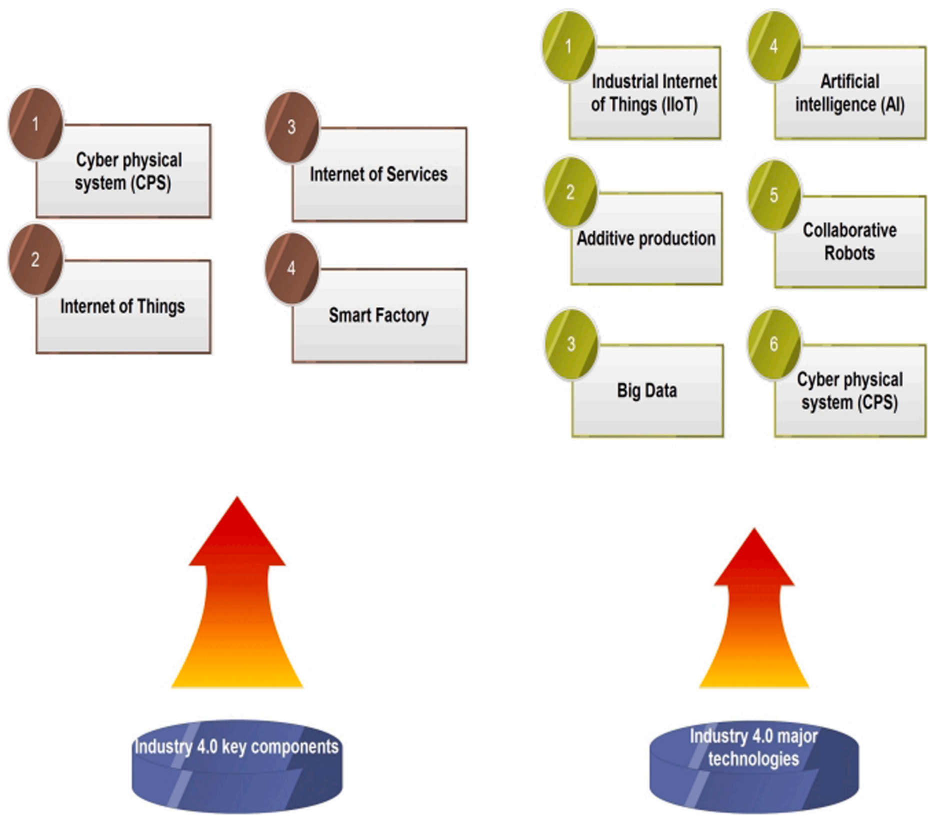

Fig. 8. Industry 4.0 components and technologies (Kiran et al., 2020).

increased revenue, security, innovation, cost reduction, and scalability (Paschek et al., 2019; Kiran et al., 2020).

After Industry 4.0 next industrial revolution is Industry 5.0 and is emerging in parallel with Industry 4.0. Industry proposes human–machine coworking (Demir et al., 2019) and intending to give out the barrier between the real and virtual world and essential for customers requiring personalized products. Industry 5.0 is defined as “Faster, more reliable and more people concern than previous one through the kinds of technology and their disposal” and “… focused on combining human beings’ creativity and craftsmanship with the speed productivity and consistency of robots”.

For industry 5.0 them exists two visions namely human-robot co-working and bioeconomy

1. In human-robot co-working creativity is defined as the domain of humans and the rest as the working domain of robots.
2. Bioeconomy intends to use biological resources for achieving the balance between ecology, industry, and economy

Industry 5.0 offers the advantages of human-robot co-working but this gives rise to many challenges such as work ethics, acceptance of robots at the workplace, differentiation between humans and robots, education, training, restructuring the workplace, and work ethics (Paschek et al., 2019). In the article (Faruqi, 2019) Industry 5.0 and Society 5.0 terms are interchangeably used and are defined as “A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyber-space and physical space”. Industry 5.0 has been considered as a strategy that allows humans to concentrate more on planning and combining human workmanship and automation. The role and application of Industry 5.0 in the agriculture sector is also emphasized in (Fukuyama, 2018) for automating repetitive troublesome tasks with the use of robots such as plowing and sowing. Here also the humans are placed in a

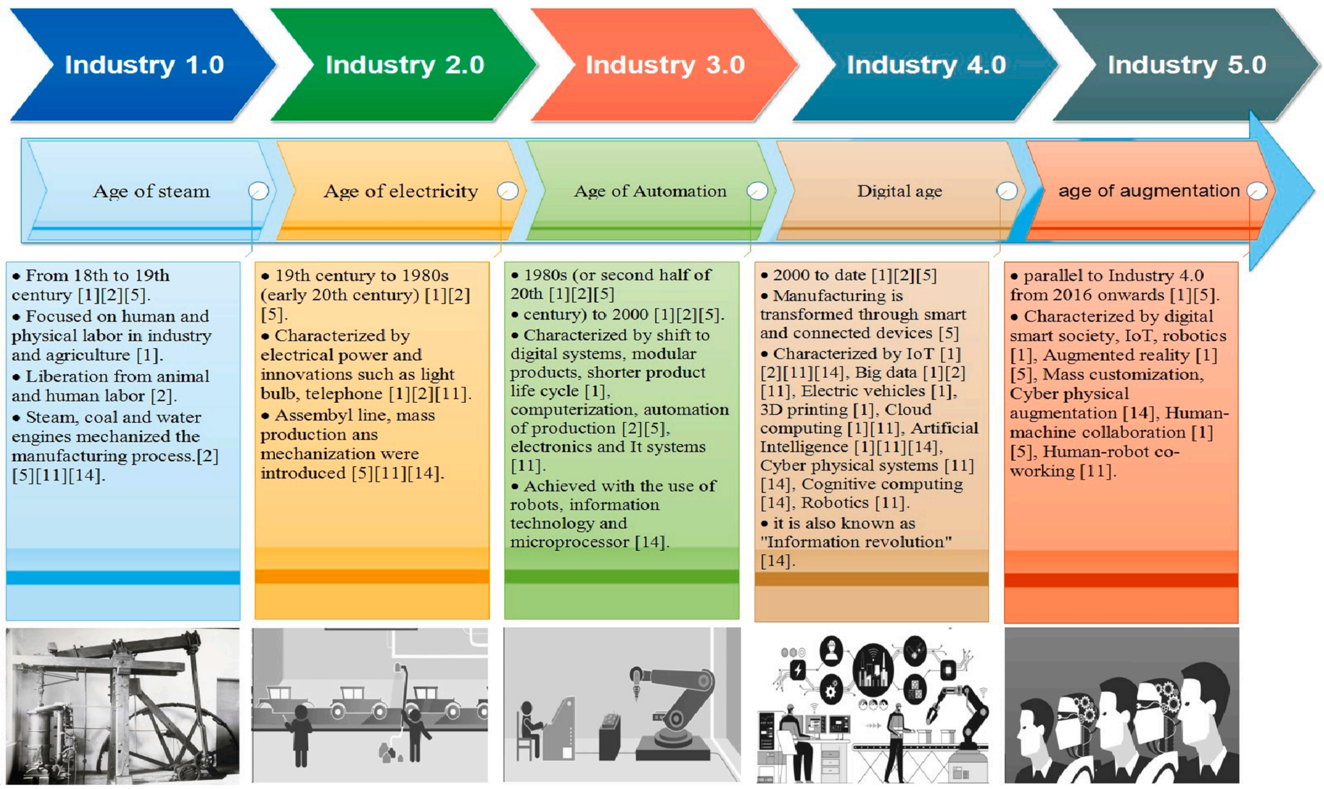

Fig. 9. Journey from Industry 1.0 to Industry 5.0.

supervisory role (Faruqi, 2019). Industry 5.0 or society 5.0 are the concepts recognizes as a digital society (Skobelev and Borovik, 2017), human-centric innovations (Carayannis et al., 2021), and is meant for human security and well-being (Shiroishi et al., 2018). Industry 5.0 uses the connection between "people and things" and between the "real and cyber world" to provide efficient and effective solutions to societal problems. The main element of Industry 5.0 as identified are IoT, AI, robotics, big data, and blockchain. Society has evolved from society 1.0 characterized by hunting and human coexistence with nature to the present new model of society 5.0 an information society. The evolution of society from 1.0 to 5.0 is depicted in Fig. 7 (Fukuyama, 2018).

The works of literature (Fukuyama, 2018; Shiroishi et al., 2018) also recognized smart cities, smart agriculture, and smart food as an integral part society 5.0 or digital society. Industry 4.0 combines the physical world with the "virtual twin" and is based on the majority of four key components and six major technologies as shown in Fig. 8 In Industry 5.0 penetration of artificial intelligence in people's common life has also been identified. The research has mentioned that the enhancement of individual capacity by bringing them to the center of the Universe. It is emphasized that rather than Industry 5.0, Society 5.0 is a better and accurate term for the newly developed paradigm and revolution industry. As for Industry 4.0, the focus of Industry 5.0 or Society 5.0 is not restricted to only manufacturing but also inclined towards solving the societal problems and related issues by availing the advantages of integrating the physical and virtual world (Skobelev and Borovik, 2017).

Industrialization is the process of performing social and economic activities to discover efficient and effective ways of creating values (Kiran et al., 2020). Industrialization has witnessed three industrial revolutions in the last 100 years since the 18th century. The fourth industrial revolution took place around 40 years and there are all possibilities that the fifth industrial revolution may be observed in less than 40 years. The journey from Industrial 1.0 to Industry 5.0 along with the major duration of each industrial revolution, their characteristics, and major technological revolutions are depicted in Fig. 9. The industrial revolution all started with steam engines recognized as Industry 1.0 and moved to Industry 4.0 recognized as the digital age with all smart and connected devices. Currently, a new paradigm is progressing in parallel to Industry 4.0 i.e. Industry 5.0 which aims to bring humans back into the process. Industry 5.0 is characterized by human–machine collaboration and human-robot coworking.

2.2. Smart cities

It was 2007 when the population inhabiting urban centers overtook the rural population. (Angelidou, 2015). Cities are invented and developed by humans with the aspect of security, proving the benefit of living together, small mobility distance, improved quality of life, and managing resources easily. Urban centers or city's population across the world is continuously increasing and currently, cities are accommodating half of the world's population even though cities only occupy less than 3% of the Earth's land surface (Gharaibeh et al., 2017; Wang et al., 2019). As per the prediction made in various works of literature city's population is expected to be 75.44 billion against the world population of 7.99 billion by 2025 (Deakin and Al Waer, 2011); up to 66% population will be residing in cities and this is as per United Nations (Ahvenniemi et al., 2017), 60%-70% of world population by 2050 (Orsini et al., 2013) The key element of smart cities is communication like communication of energy, information system, monitoring devices, and service control, etc. (Zubizarreta et al., 2016). The role and significance of Information and Communication Technology (ICT) has been explained and emphasize in various works of literature (Martin and Molin, 2019; Mohanty et al., 2016; Ibarra-Esquer et al., 2017; Longo et al., 2020; Zhang et al., 2018; Ávila-Gutiérrez et al., 2021; Chen et al., 2021; Haleem and Javaid, 2019; Kiran et al., 2020; Angelidou, 2015; Wang et al., 2019; Al-Smadi et al., 2019; Albino et al., 2015; Zubizarreta et al., 2016; Mehmood et al., 2017; Park et al., 2018). ICT has provided the tool to support smart cities (Zubizarreta et al., 2016), the building of ICT-based infrastructure is required for optimizing resource utilization. Operations and exploring new opportunities (Kiran et al., 2020); the technological developments use ICT for ur ban area function such as

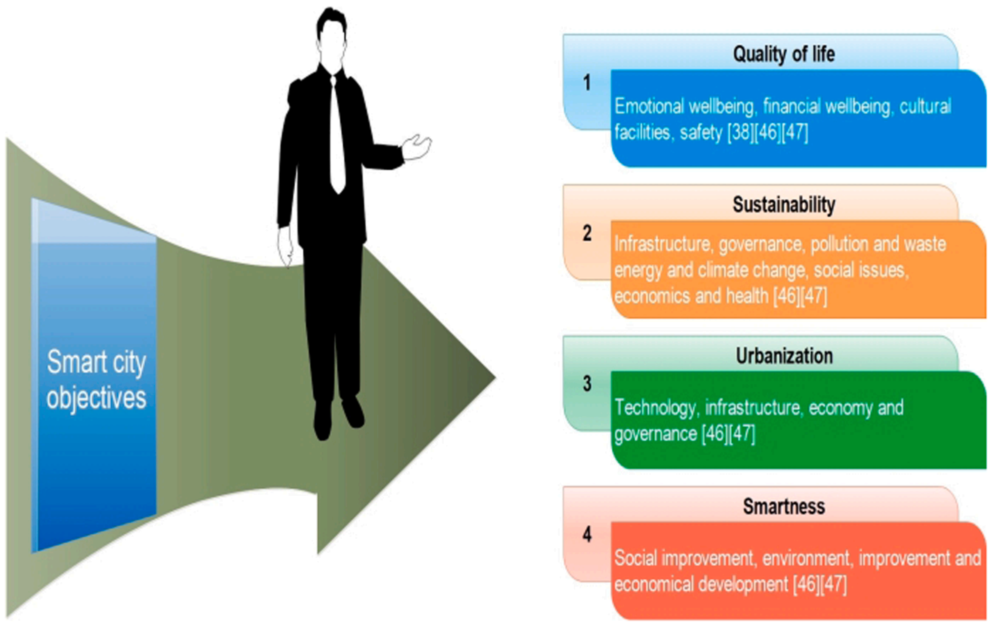

Fig. 10. Smart city objectives and their aspects (Mohanty et al., 2016; Albino et al., 2015; Silva et al., 2018).

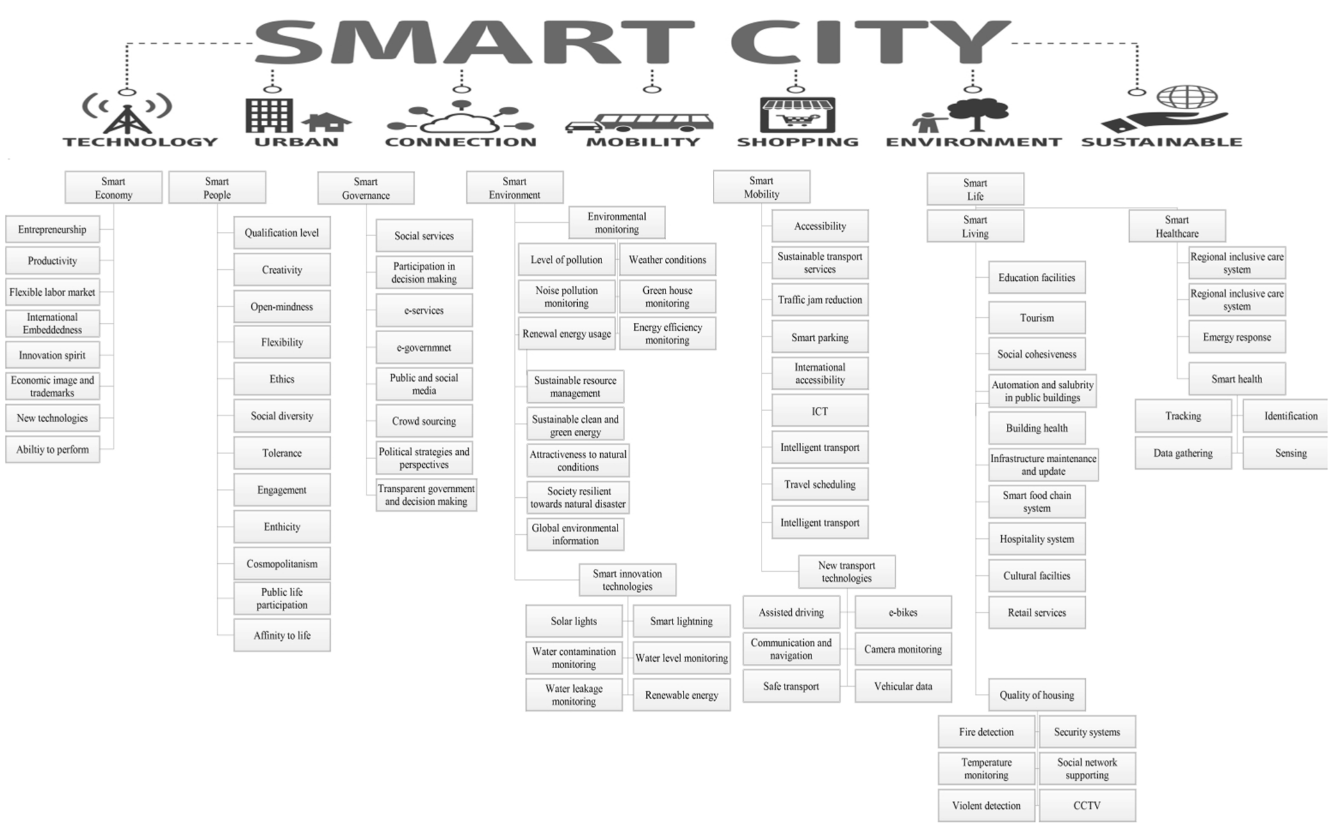

Fig. 11. Smart city concept and applications (Alavi et al., 2018; Ben Letaifa, 2015; Mohanty et al., 2016; Kiran et al., 2020; Albino et al., 2015; Zubizarreta et al., 2016; Silva et al., 2018; Zanella et al., 2014; Arasteh et al., 2016; Mehmood et al., 2017; Talari et al., 2017; Pellicer et al., 2013; Shiroishi et al., 2018).

transport, healthcare, water, waste, etc. (Angelidou, 2015); smart cities integrate 2.0 technologies with ICT for urban planning by using innovative and feasible solutions (Ben Letaifa, 2015). ICT has been identified as a critical component in smart city infrastructure (Deakin and Al Waer, 2011); ICT together with modern technologies are the key to the smart cities (Ahvenniemi et al., 2017); ICT is the key enabling technologies for transfiguring the conventional cities to smart cities (Mohanty et al., 2016), a city gets unifies and coordinates the city services through ICT and provides a way for efficient and reasonable utilization of city's resources (Simon and Mester, 2018). For smart cities there exist a piece of limited information and understanding about the trends, concepts, technologies, and relationships between technology and smart city (Özdemir and Hekim, 2018). When it comes to defining the smart city there exist many definitions in various published works of literature

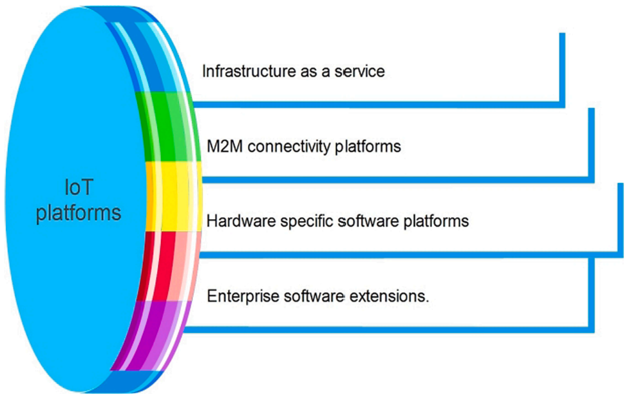

Fig. 12. Categorization of IoT platforms based on supported features and services (Park et al., 2018).

ranging from the technical aspect to the definition considering social aspects. In (Ahvenniemi et al., 2017; Alavi et al., 2018; Ben Letaifa, 2015; Gharaibeh et al., 2017; Gharaibeh et al., 2017; Yigitcanlar et al., 2020; Patel and Doshi, 2019; Al-Smadi et al., 2019; Albino et al., 2015; Angelidou, 2015; Zubizarreta et al., 2016) smart city is described as a city that uses digital technology and ICT to boost city's development and also improves sustainability of city.

After defining the smart cities, it becomes important to review various elements or components and applications which make a city smart. The main features of intelligent cities are electronic and digital technologies, Information Technology, ICT, and bringing of smart ICT and people together. The components of smart cities as mentioned in (Longo et al., 2020) are education, industry, technical infrastructure, economy, governance, environment, participation, living, mobility, and people. A smart city is an establishment where electronic and digital technologies along with ICT are exploited to create a cyber digital knowledge-based city with certain objectives as mentioned in Fig. 10 (Mohanty et al., 2016; Albino et al., 2015; Silva et al., 2018).

Smart cities are characterized by four core themes and six major components or applications. The four core themes of smart cities are

- Society: which signifies the importance of citizens in the city,
- Economy: which related to the job and economic growth,
- Environment: relates to city's sustainability for present and future,
- Governance: relates to sturdiness in administration policies.

Physical, social, economic, and economic institutional infrastructures are yet another four core themes identified as four pillars of a smart city (Silva et al., 2018). Governance and public, private, and civil organizations are considered under institutional infrastructure while human resources, Quality of Life, aware citizens with responsibility and commitment towards society, and intellectual capital are the various aspect of social infrastructure. Career advancement, reach to micro and macro economy both, e-commerce and e-business are some the important consideration in economic infrastructure pillar of the smart city. The physical infrastructure pillar of smart cities focuses on the importance of resource sustain- ability for continuing the operation in the present and future and technology in a smart city. ICT infrastructure along with the smart devices and networks supports the accomplishment of smart cities. The various works of literature have also identified six major applications/components/characteristics of smart cities namely smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. Each component or applications of the smart city is also associated with sub-aspects or applications as elaborated in Fig. 11 adapted from (Alavi et al., 2018; Ben Letaifa, 2015; Mohanty et al., 2016; Kiran et al., 2020; Albino et al., 2015; Zubizarreta et al., 2016; Silva et al., 2018; Zanella et al., 2014; Arasteh et al., 2016; Mehmood et al., 2017; Talari et al., 2017; Pellicer et al., 2013; Shiroishi et al., 2018). All the aspects or applications presented in Fig. 11 are interrelated. All environmental activities are related to mobility and the economy. For instance, energy-saving is considered to be an environmental application and is closely related to economic saving. Similarly, governance and people are interrelated as without active and involved citizens and the government's willingness to let people participate in the daily life of the city, smart people, and the government is meaningless.

2.3. IoT and key enabling technologies for smart cities

2.3.1. IoT and smart cities

The model of Barcelona smart city is discussed in (Gea et al., 2013). In this, the authors have discussed that smart city technologies need to be considered at both hardware and application level. In addition to this sensing in a smart city is heterogeneous due to multiple technologies and management devices. From the implementation point of view, the authors have considered sensor capabilities, gateways, transport networks, data management, and front-end application as the main elements of a smart city. The IoT technology used for smart cities is termed "Urban IoT" which aims to provide the communication infrastructure to access public services. "Urban IoT" is characterized by the ability to integrate different technologies of communication infrastructure and realizing unconventional functionalities (Zanella et al., 2014; Mehmood et al., 2017). The authors have also provided architecture of "Urban IoT" considering IoT, sensors actuators, and wireless access network at the root level of a smart city. Devices based on IoT are becoming smarter and smarter and intelligent than before. IoT provided the foundation to smart a city through smart, intelligent, and self-configuring objects connected via a global network. IoT offers a novel approach for connecting the digital services of a city to citizens. Scalability, heterogeneity, end-user involvement, and flexibility are some of the aspects of smart cities based on the network type. The smart city technologies as enlisted in (Mehmood et al., 2017) are RFID, WSN, WiFi, WPNA, WLAN, GSM, 3G, etc. (Arasteh et al., 2016; Mehmood et al., 2017).

IoT is materializing as a building block for the smart city by addressing most of the critical issues faces such as mobility, civil infrastructure, or health care by creating a worldwide network of connected devices equipped with software, sensors, and electronics for connected objects. Application and technology domains are the two areas in which IoT for the smart city has been classified, Technology domain deals with communication protocols, smart technologies with their pros and cons while the application domain is concerned about the development of IoT in different areas like WSN, intelligent wheelchairs, Industrial networks, and many more (Alavi et al., 2018). IoT has been considered as the future of the internet with "things" having identities to communicate with each other. IoT is deployed in various applications such as agriculture, environment monitoring, health care, and smart cities also. US president in 2009 has also given the concept of "smart earth" based on IoT involving installation of sensors and in the same year, European Union had validated "IoT Strategic Research Roadmap" to promote, share and propagate IoT linked projects research and associated outcomes particularly in the areas of sensing technology. From a smart city point of view, IoT platforms can be considered in four major categories namely the environment, enterprise, company, and pure business. In environment services to smart city improves local, regional, and national government. To improve and enhance competitiveness, IoT projects aids in providing better management, logistics, distribution systems with company-based IoT platforms. Pure business platforms help in boosting the modern economy by integrating and optimizing market information resources including end-user and terminal equipment (Ganchev et al., 2014).

IoT has opened the doors for new opportunities to monitor and manage devices remotely, analyzing information from various real-time data streams and taking the decision based on analyzed data, and has enabled many of the smart city projects across the world. For an efficient

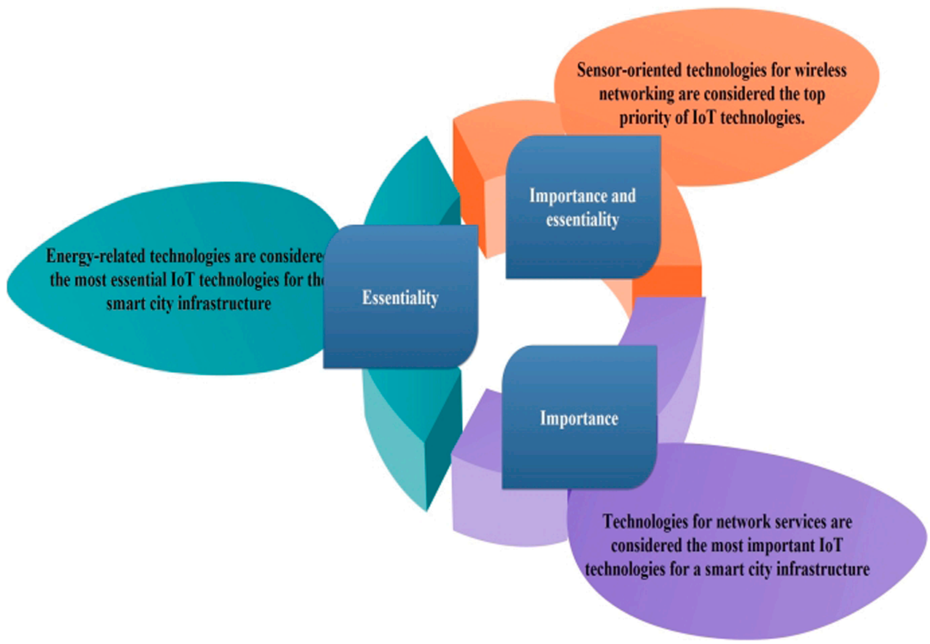

Fig. 13. Future direction for IoT in smart city applications (Park et al., 2018).

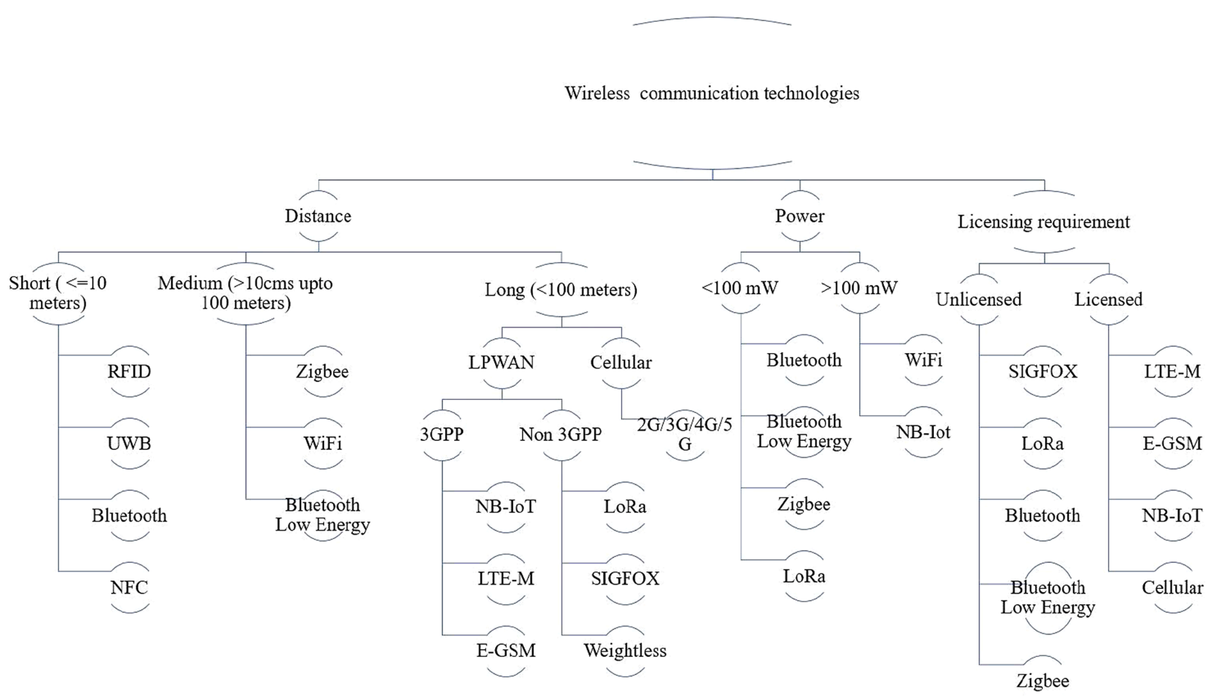

Fig. 14. Classification of wireless communication technologies for IoT (Talari et al., 2017; Hammi et al., 2018; Feng et al., 2019; Poursafar et al., 2017).

IoT solution to smart city, IoT should be able to

- bring down the cost and possible risk involved in creating an IoT network
- connect multiple and heterogeneous systems of a city.
- deploy IoT services, which are an integral part of a smart city in a shorter duration.
- Provide secure and scalable services with new options for a city.
- Add values to the provided services through connected devices.

For achieving the different goals for an IoT platform, different IoT platforms can be categorized into four groups as provided in Fig. 12. Different IoT solutions and products are changing the view of cities through enhanced infrastructure, improved transportation, delivery efficiency, and cost-effective solutions to municipal services, reduce traffic congestion, and enhanced citizen's services.

IoT is the key technological infrastructure smart cities (Park et al., 2018) and smart city is considered an important application of IoT (Fukuyama, 2018). In article (Park et al., 2018), IoT has been interpreted as "a set of technologies for accessing the data collected by various devices through wireless and wired Internet networks". With the focus of smart city towards using energy and electricity in efficient way,

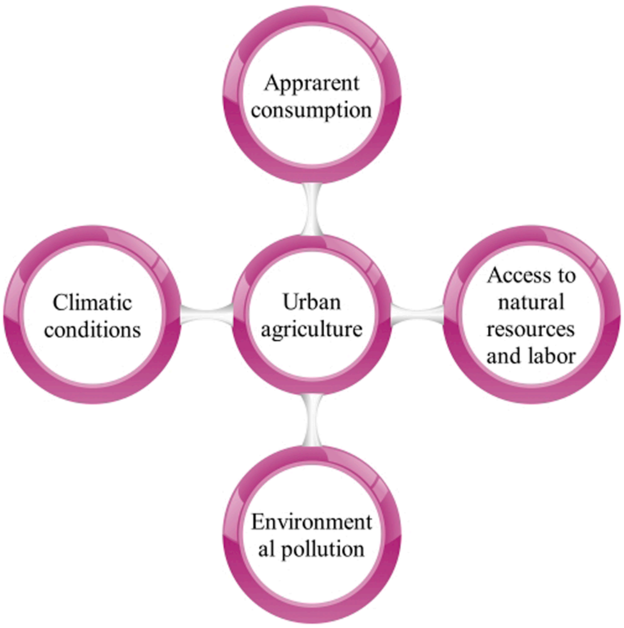

Fig. 15. Factors in influencing the development of urban agriculture (Orsini et al., 2013).

furnishing good infrastructure for society. IoT has gained much popularity. Moreover, the role of IoT in smart cities is further magnified with the development of different kinds of networks (Park et al., 2018) and technological improvements in the area of ambiquitous computing, M2M communication, and WSNs (Silva et al., 2018). The development of IoT-based technologies for various services in a smart city provides sustainable and satisfying living conditions for its citizens. But to deliver successful and efficient IoT technologies in near future three points, as shown in Fig. 13, are of paramount importance and need to be focused on (Park et al., 2018).

A smart city is recognized by different names such as “cyberville”, “digital city”, “electronic city”, flexibility, etc. but a smart city is more frequently used as it encloses other labels for cities. IoT has been identified as the technological backbone of a smart city with three key features namely intelligence instrumentation and interconnection (Mohanty et al., 2016) and also line up with the objective of tracking, locating, managing devices intelligently identification, monitoring with timely improvement in communication technologies between human to machine, or things, things to human and amongst machine or things. ICT, IoT, and Big data are the key enabling smart city technologies for transfiguring conventional cities into smart cities. The deployment of IoT in the city’s infrastructure makes the concept of smart city feasible, workable and realizable (Sumi and Ranga, 2016).

2.3.2. *Key enabling technologies for smart cities*

In the transformation of a conventional city into a smart city, the three key technologies identified are IoT, ICT, and Big and are interrelated as one depends on the other. Out of the three key technologies, ICT plays an important role as it connects all other components of the smart city. ICT infrastructure makes the city’s services such as hiring a cab, making credit card advanced with NFC, accessible (Mohanty et al., 2016). The various communication technologies employed for data

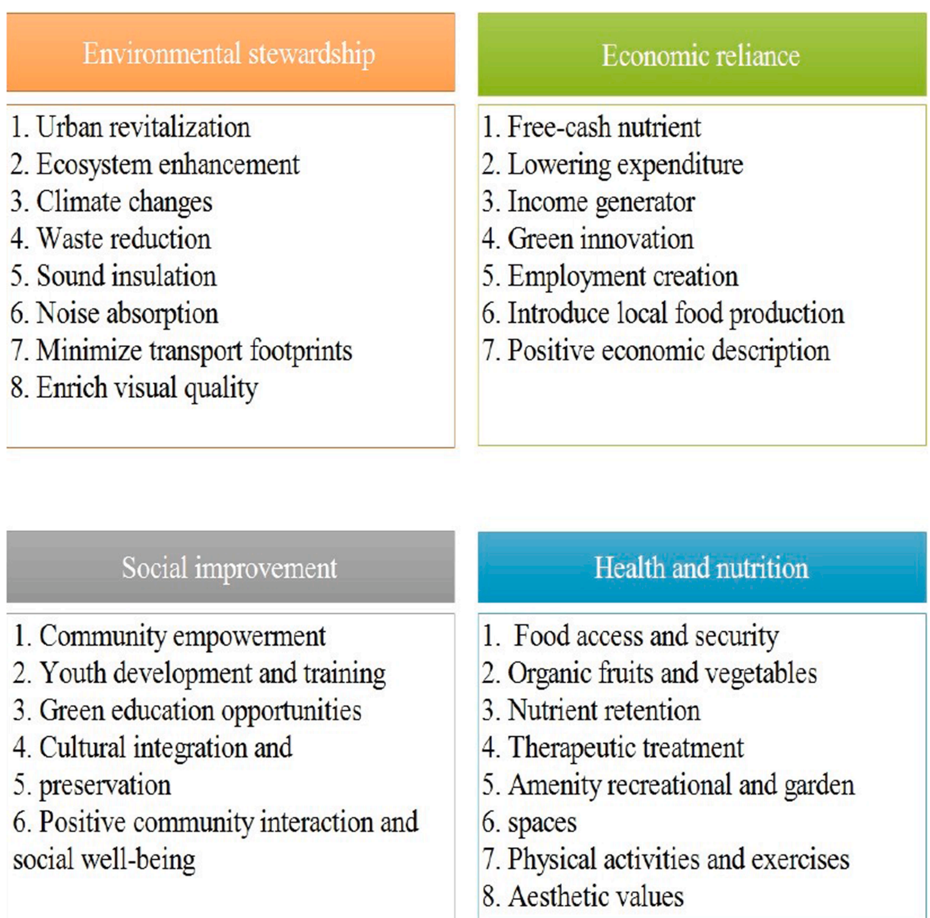

Fig. 16. Benefits of urban farming (Yusoff et al., 2017).

transfer in IoT are consist of NFC, Bluetooth, fiber optics, WiFi, LTE, RFID, 6LowPAN, UWB, Zigbee, GSM, GPRS, Bluetooth Low Energy (Alavi et al., 2018; Mohanty et al., 2016; Zanella et al., 2014; Mehmood et al., 2017; Gea et al., 2013). NFC is mainly used for communication with 10cms and RFID is the first technology being used for M2M communication. UWB supports high bandwidth communication within a small communication distance radius. In addition to the well-known wireless communication technologies, LoRa and SIGFOX are the technologies recently finding way to the smart city. LoRaWAN protocol supports interoperability in smart cities and SIGFOX is an ultra-narrowband radio technology offering a scalable network for smart cities (Alavi et al., 2018). Various communication technologies along with their aspects such as applications, coverage range, technical details are provided, and different WSN technologies used in IoT are classified on the ground of their coverage range and power consumption (Talari et al., 2017; Hammi et al., 2018; Feng et al., 2019). Other than distance range and power consumption, IoT communication technologies are also classified based on being a member of 3GPP or not (Islam et al., 2021) and are licensed or unlicensed technologies (Poursafar et al., 2017). The classification of various wireless communication technologies for IoT applications in smart cities is shown in Fig. 14.(see Figs. 15 and 16)

2.4. Urban farming and irrigation

Smart cities applications are enlisted in Fig. 11 and the various key enabling technologies for smart cities are shown in Fig. 14. Apart from the applications depicted in Fig. 11, agriculture is one area that plays an important role towards economy and protection to environment theme (Silva et al., 2018) and sustainability objective (Ahvenniemi et al., 2017) of smart city, and it is not much highlighted as a core element of a smart city.

Urban agriculture involves miscellaneous activities such as livestock management, crop cultivation, aquaculture, and poultry (Mason et al., 2019). And clothing, building material, and medicinal herbs are some of the additional requirements from urban farming. Agriculture has penetrated onto the city's boundaries where it is profitable to trade due to the availability of advanced logistics cheap manpower and a good scale of production (Tsyplakova et al., 2020). Farming in urban areas is also getting digital and is now called "Digital urban Agriculture" (DUA) utilizing silicon-based hardware automated equipment and software for agricultural operations. Urban agriculture has also raised the property value by about 9% and is recognized for alleviating food insecurity and improving livelihood through easy food access. It is also getting linked with symbolic and cultural developments (Carolan, 2020).

Rural and urban farming face many challenges and few of them are common to both. Some of the challenges specific to the urban farming identified through literature survey, social establishment and observations are high land value, less land space, contaminated soil. Major challenges faced by rural farming are learning and adoption of new technology, investment options, transportation, rapidly depleting reserves for fresh water. Feeding the fast-growing population, crop damage by birds, inefficient utilization of agricultural resources like irrigation water, fertilizers and rapidly depleting reserves for fresh water are some of the challenges collectively faced by both rural and urban farming. The present work is focused on precision irrigation (efficient utilization of irrigation water) under the perspective of Industry or Society 5.0 and smart city.

2.4.1. Irrigation in urban farming

The main activities associated with crop production in agriculture are fertilization, application of pesticides, plant growth regulators, and most importantly irrigation (Orsini et al., 2013; Martin and Molin, 2019; Bon et al., 2010; Tsyplakova et al., 2020). Water is an important element in maintaining plants in urban and identifying soil type, plant type and season has a decisive impact on irrigation planning. Many of the plants require to be irrigated after being planted and if not properly irrigated gets stressed which influence their growth. As under irrigation is detrimental similarly over-irrigation is also detrimental resulting in food, running off soil nutrients, and required chemicals that pollutes other water resources (Rizzo et al., 2020). To monitor and control both over and under irrigation variety of available useful tools such as rain and soil moisture sensors may be deployed. To estimate the irrigation requirement of plants or crops suitable methods need to be used and it has been reported that reference evapotranspiration-based irrigation adaption results in up to 62% of water-saving (Canales-Ide et al., 2019; Johnson and Belitz, 2012; Vahmani and Hogue, 2014). Irrigation is important in areas where plants are not adapted to climatic conditions and need to be irrigated (Vahmani and Hogue, 2014).

The scarcity of water, high dependency on irrigation (Department of Agriculture, Cooperation Farmers Welfare Ministry of Agriculture Farmers Welfare Government of India, 2018; Dhawan, 2017) coupled with irregular rainfall, and high temperature are some of the obstacles to the growth of plants (Caetano et al., 2014) and is found that the majority of the irrigation water is wasted owing to negligent usage (Solanki et al., 2017). One of the possible ways to address the challenge is wastewater treatment which allows it to enter watercourses for irrigation purposes. Other than this, various IoT-based systems such as iRain (Caetano et al., 2014) and soil moisture-based irrigation systems (Solanki et al., 2017) are also developed. In IoT-based irrigation systems, irrigation is planned as per weather forecasting (Caetano et al., 2014) and soil moisture estimation (Solanki et al., 2017) resulting in large-scale savings of resources and energy. Inefficient planning of irrigation can lead to over usage of water up to 700% and to improve sustainability in urban living less efficient and inappropriate irrigation scheduling needs to be taken care of. The article (Canales-Ide et al., 2019) takes reference evapotranspiration and weather station data for irrigation planning for the park. The article has also taken smart irrigation as a part of the global concept for smart cities in the context of water scarcity and the need for water usage efficiency. There exist two different methods for estimating plant water requirement namely indirect method based on reference evapotranspiration and direct method based on soil moisture sensors (Canales-Ide et al., 2019).

With the increase in the world population and decrease in agricultural land, there is a grave challenge of providing sufficient food to the increased population. To increase the efficiency of the agriculture sector, Precision Agriculture is being used and is the method to improve the efficiency of agriculture by maximizing food production and minimizing the environmental impact. Precision Agriculture implementation majorly depends on three important parameters namely real-time monitoring and data acquisition, data analysis and decision making, and finally precise treatment based on the decision. All three factors can easily be achieved through IoT. IoT provides network infrastructure with smart and intelligent devices for data collection, provides a facility for data processing and decision making, and finally the implementation of the decision made on the cloud to get implemented in farms. Irrigation is one of the most important aspects of Precision Agriculture and consumes about 70% of the freshwater available for human consumption due to traditional methods of irrigation, which may lead to water scarcity along with the impact on the environment. Irrigation water efficiency can be improved by incorporating a crop-demand-dependent or Crop Water Stress Index (CWSI) based irrigation scheduling (Zhang et al., 2018). Precision Agriculture in urban farming apart from providing a means to increase irrigation water efficiency also helps in managing thermal water stress and energy consumption of the city in the hot season.

3. Precision irrigation monitoring system

The objective of Society 5.0 is to create a super-smart society with a human-centric approach for sustainable de- velopment (Carayannis et al., 2021; Fukuyama, 2018) and a smart city is an establishment for a

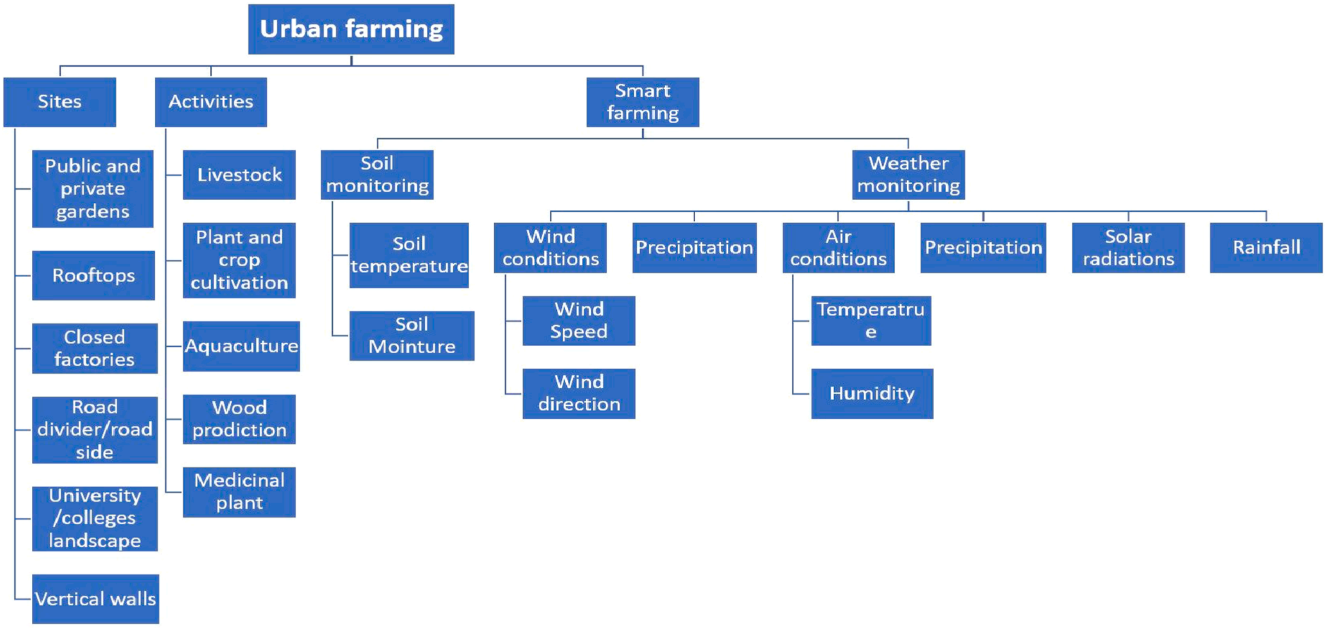

Fig. 17. Various dimensions of Urban farming (Orsini et al., 2013; Bon et al., 2010; Yusoff et al., 2017; Mason et al., 2019; Canales-Ide et al., 2019; Solanki et al., 2017; Math and Dharwadkar, 2018; El-magrous et al., 2019; Mestre et al., 2015; Hong et al., 2015).

Fig. 18. The concept of the developed system for Precision Irrigation monitoring.

sustainable environment, quality of life, good resource efficiency (Gharaibeh et al., 2017; Zubizarreta et al., 2016), livable life (Ahvenniemi et al., 2017; Alavi et al., 2018; Al-Smadi et al., 2019). Thus, the objectives of both Society 5.0 and a smart city are to provide a sustainable, good quality of life, protection to the environment and to attain these objectives apart from the applica- tions and aspect mentioned in Fig. 10 agricultural activities such as crop cultivation, livestock management, planting, aquaculture poultry, etc. (Mason et al., 2019) contribute significantly by providing food security, health (Orsini et al., 2013), source of income, im- proved city's green space and urban reinvigoration (Yusoff et al., 2017). With the urbanization and increase in population, there is a need for urban agriculture for attaining the objective of Society 5.0 and a smart city. Fig. 10 mentions almost all the aspects of a smart city but fails to put light on urban farming because while considering a smart city, urban irrigation is somewhat neglected in all the published literature. The various dimensions of urban agriculture are presented in Fig. 17 as adapted from (Orsini et al., 2013; Bon et al., 2010; Yusoff et al., 2017; Mason et al., 2019; Canales-Ide et al., 2019; Solanki et al., 2017; Math and Dharwadkar, 2018; El-magrous et al., 2019; Mestre et al., 2015; Hong et al., 2015). In precision agriculture, technology is used to monitor the various parameters of agriculture for efficient planning and resource management. In this also IoT shows its importance through data collected using smart devices, data processing, and decision making.

Table 1
LoRa Characteristics.

Characteristics	LoRaWAN
Topology	Star on star
Modulation	SS chirp
Data rate	290bps-50Kbps
Link budget	154 dB
Packet size	256 bytes
Battery life	8–10 years
Power efficiency	Very high
Security	Yes-32bits
Coverage range	2-5Km in urban areas 15Km in suburban areas 45Km in rural areas
Immunity to interference	Very high
Scalability	Yes
Mobility	Yes

Fig. 19. Wind direction and wind speed sensor.

Fig. 20. Wind direction mapped to sensor.

Table 2
DHT11 Vs DHT22.

Specification	DHT11	DHT22
Temperature range	−20 to 60 °C	−40 to 80℃
Temperature accuracy	±2%	±0.5
Humidity range (Relative Humidity)	5 to 95%	5 to 95%
Humidity accuracy	±5%	±2%

Table 3
Soil moisture sensor calibration equations.

Sensor output (in voltage)	VMC calibration equation
0–1.1	10*V-1
1.1–1.3	10*V-1
1.3–1.82	10*V-1
1.82–2.2	26.32*V- 7.89
2.2–3	62.5*V − 87.5

Precision Irrigation based on plant/crop demand can be adopted through indirect method or direct method by measuring soil moisture using soil moisture sensors probe. The system developed and presented in this\ article uses the direct method for estimating the irrigation requirement. The Field monitoring face challenges of power efficiency and coverage range for which ZigBee is not a suitable solution as in the case of facility monitoring, which is controlled environment monitoring. The conceptual visualization of the developed system of Precision Irrigation monitoring is given in Fig. 18. The system consists of sensor nodes for collecting soil conditions i.e., soil temperature and soil moisture from different parts of field. The central node i.e., weather station collects the soil conditions from every soil sensor node and also measures the weather conditions of the agricultural field. All the information i.e., weather and soil conditions are uploaded to the IoT cloud which enables the farmer to precisely monitor the real-time field condition of the field for irrigation requirements.

3.1. Wireless communication technologies

The IoT wireless communication technologies for agricultural application are presented in (Feng et al., 2019). Zigbee is considered a favored choice for facility monitoring i.e., greenhouse monitoring while LoRa and NB-IoT are considered the better choice for field agriculture monitoring. From a power consumption perspective, Bluetooth is the best choice but suffers from the limited range. Zigbee is although having a range of up to 100 m and is power sufficient but for field agriculture applications, the range is still insufficient and is only suitable for facility agriculture applications. If long-range and power trade-off is taken into account, LoRa and NB-IoT are the suitable technologies with a range maximum up 15 Km at about 100 mW of power consumption but NB-IoT works on the licensed band while LoRa work on the unlicensed band of frequency, thus for field monitoring on the parameters on cost, coverage range, and power consumption, LoRa is a better choice in terms of range, power consumption, and scalability. The different characteristics of LoRa are provided in Table 1 (Feng et al., 2019; García et al., 2020).

3.2. Precision irrigation parameter selection

Soil temperature, soil moisture, and weather conditions such as air temperature and relative humidity wind speed, and wind direction are the most critical parameters of agriculture which greatly affects agricultural productivity and irrigation planning. Soil temperature and soil moisture affect the availability of nutrients to plants. The optimal soil temperature for nitrification and ammonification is 20 degreeC to 25 degreeC and soil moisture is 80%, for nitrogen (Guntiñas et al., 2012; Sierra, 1997; Ellert and Bettany, 1992; Grundmann et al., 1995; Hunsigi, 1975). Soil temperature also affects the water uptake by plants, plants take nutrients from the soil through the water. An increase in rooting temperature from 14 degreeC to 26 degreeC improves the water uptake of plants by 30% (Kuiper, 1964; Lv et al., 2013; Hurd and Graves, 1985; Yoshida and Eguchi, 1989). Soil temperature is mainly affected by solar radiation, vegetation coverage, soil color, and many other factors including soil moisture content. Maintaining proper soil moisture content also helps to maintain soil temperature suitable for plant growth. Soil temperature also harms soil moisture content as with temperature water viscosity decreases which results in penetration of more water

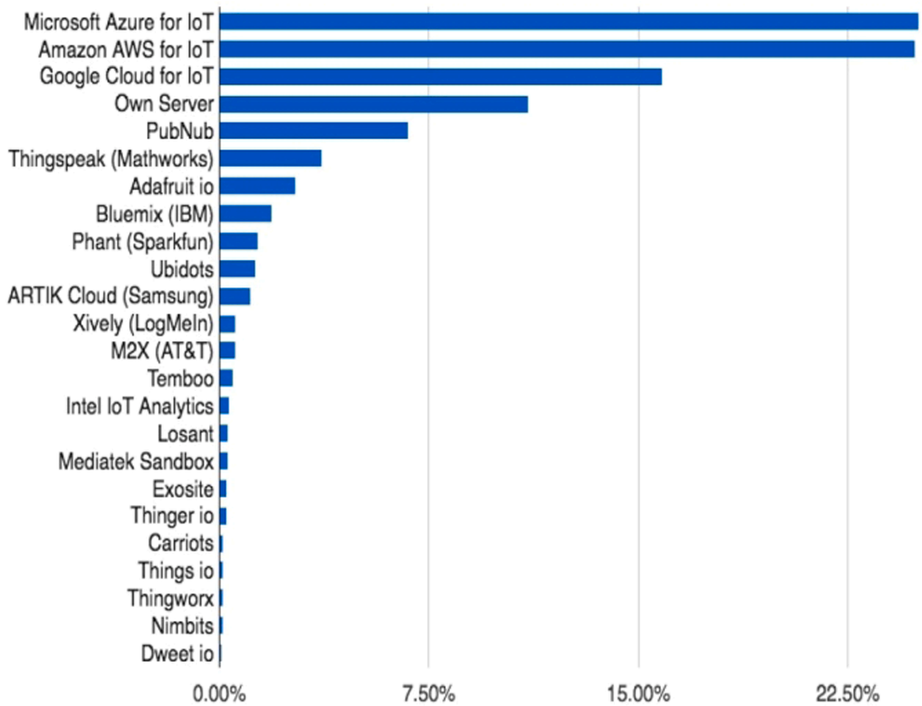

Fig. 21. IoT platforms with market share (Thingspeak.com., 2021; Kamienski et al., 2019).

Fig. 22. Wireless soil sensor node.

Fig. 23. Lab setup of weather station.

through the soil profile. Increased soil temperature also affects the availability of nutrients to plants by improving soil metabolic activities (Onwuka, 2016; Hood, 2001; Wilcox and Pfeiffer, 1990; Keane and Kerr, 1997). Soil temperature and soil moisture content also have a decisive impact on the development of diseases in crops and plants. In a study, it

Fig. 24. Weather station at work.

has been identified that plants develop minimum disease from 27 °C to 30 °C and are completely immune to diseases at temperatures from 19 °C to 20 °C. Similarly at 30% to 33% of soil moisture is much suitable for disease development in plants and soil moisture from 13% to 14% shows minimal disease development in plants (Keane and Kerr, 1997; Clayton, 1923; Grange and Hand, 1987; Sawan, 2018; Nyang'au et al., 2014). Wind also affects the overall yield of agriculture. Strong winds cause damage to crops through abrasion, crop lodging, and leaf tearing increasing water loss. The optimum air temperature for photosynthesis, cell division, and plant growth is 30 °C. Air temperature and humidity affect the flower and ball generation in cotton. The weather parameter important for crop growth, as experimented on rice, are wind speed, atmospheric temperature and humidity, solar radiation, precipitation, and solar radiations (Gardiner et al., 2016; Van Gardingen and Grace, 1991; Jackson and Hunt, 1975; Finnigan and Belcher, 2004; Dupont et al., 2008; Berry et al., 2004; de Carvalho Silva and Rodrigues, 2017). In Precision Agriculture, for weather and soil monitoring the most worked out parameters are soil moisture, air temperature, and air humidity but wind conditions and soil temperature are not given much importance rather they influence the agriculture yield greatly (García et al., 2020).

Based on the various works of literature, the important parameters

Fig. 25. Soil sensor node 1 data visualization.

having reasonable effects on overall agricultural yield, quality, and quantity both and irrigation demand of crops can be summarized as soil temperature, soil moisture content, air temperature, air humidity, and wind condition (speed and direction).

3.3. Monitoring wind and soil conditions

For weather monitoring, almost all wind sensors are similar in operation and only different is in their make material i.e either of plastic or metal. The wind speed sensor and wind direction sensor used in the developed system are shown in Fig. 19. The sensor to the left is a wind direction sensor and the right is wind speed. The concept of detecting wind direction is shown in Fig. 20 and is an analog sensor. The values in Fig. 20 are the ADC output count corresponding to the analog output from the wind direction sensor and are mapped with wind direction.

For atmospheric humidity and temperature, DHT 22 is the better choice as being predominantly utilized in agriculture application after DHT11. DHT22 is a digital sensor with decimal precision, is single compact single sensor of both humidity and temperature and is better in accuracy, and range than DHT11. Table 2 compares the DHT11 and DHT22 sensor's specifications (Seeedstudio.com., 2020).

In soil monitoring, soil moisture and temperature are the important parameters. For soil moisture sensing, the soil Volumetric Moisture Content (VMC) sensor is much suitable for measuring soil moisture than the comparator-based soil moisture sensor, and the, same is employed in the developed system. The calibration equations based on sensor output voltage are given in Table 3. VMS is the volume of moisture retained or present in the soil for a unit volume of soil (Vegetronix, 2021).

For temperature sensor DS18B20 encapsulated in a waterproof and corrosion-resistant case with range 55 °C to + 125 °C with an accuracy of ± 0.5 °C is used. The sensor works on a 1-wire protocol thus is efficient in term of digital pins and can easily be buried into the soil for measurement

3.4. IoT cloud for data storage and visualization

Numerous Internet of Things (IoT) cloud services is available as shown in Fig. 21 along with their market share. The developed system for Precision Irrigation with Long Range Wireless Sensor Network (LoRaWAN) uses ThingSpeak IoT platform for receiving information from field sensors and record the information in its database. ThingSpeak IoT cloud is identified as mapped with low-cost infrastructure requirements, its potential to display the data graphically and also providing mathematical analysis tool i.e. MATLAB thus enabling it to perform information processing (Thingspeak.com., 2021; Kamienski et al., 2019).

4. Result and discussion

This section provides the design of the proposed system and the results obtained after the testing of the system. Finally, the discussion on obtained results and future directions is presented. The system developed for Precision Irrigation, as provided in Fig. 18, mainly consists of four elements namely wireless soil sensor nodes with long range connectivity to weather station, IoT connected weather station, IoT cloud, and end-user monitoring device.

Soil sensor nodes are responsible for collecting the soil conditions i. e., soil temperature and soil moisture content. Wireless soil sensor nodes are to be spread across the field to collect soil conditions from different locations of the agricultural fields. Multiple soil sensors. as per need, are required to be spread throughout the field so as to closely monitor every part of the farmland. Each wireless soil sensor mode comprises a soil temperature sensor, soil moisture sensor, LoRa communication module, battery and a processing unit. Datasheet of LoRa module used claims

Fig. 26. Soil sensor node 2 data visualization.

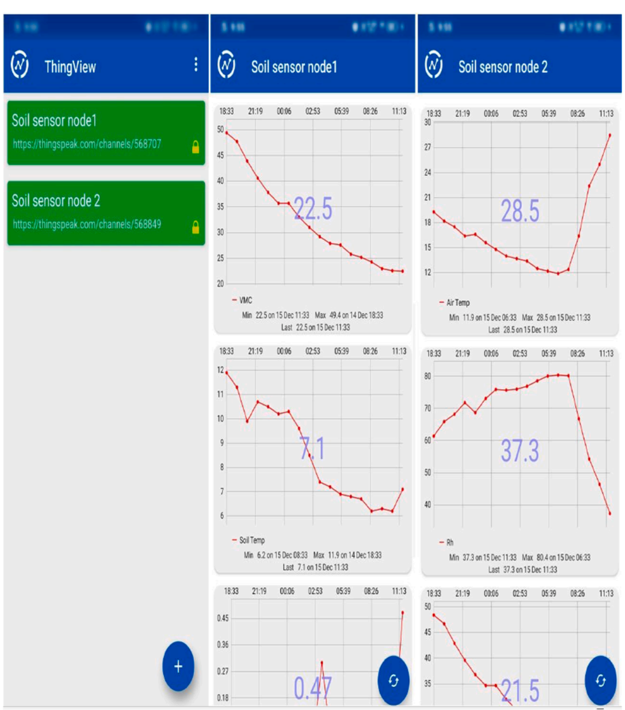

Fig. 27. Mobile phone interface for data visualization.

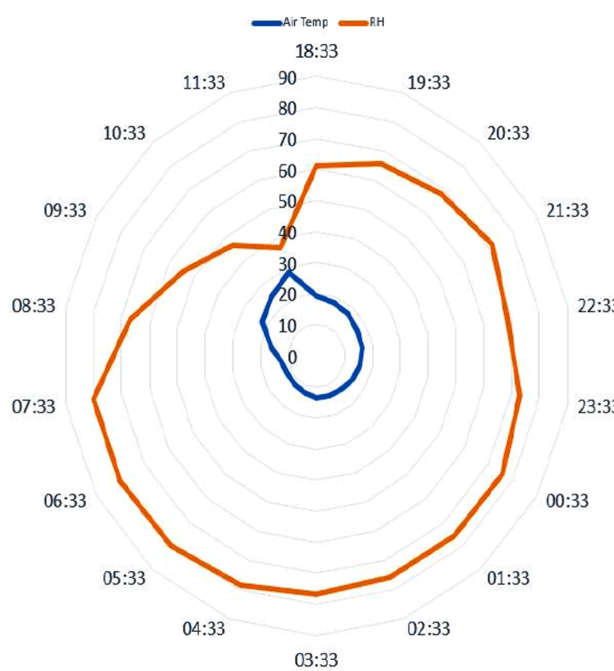

Fig. 28. Weather parameters.

distance range upto 8 Km. The module is tested satisfactorily upto 1Km to 1.5Km for the implemented soil sensor node. Temperature and moisture sensors need to withstand the harsh conditions of soil as they are to be buried in the soil for measurement and the selection of the sensors was done accordingly. LoRa communication protocol module is used as a communicating device and is responsible to transmit the soil conditions to central unit i.e., IoT connected weather station. Being a

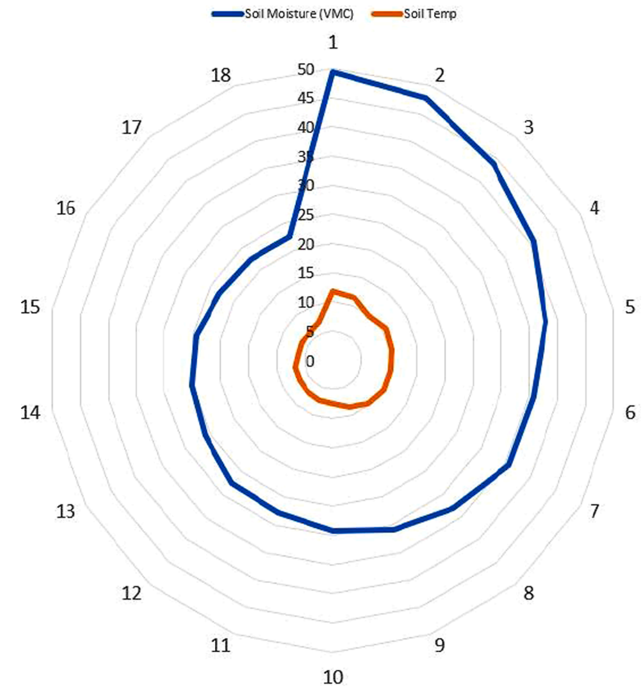

Fig. 29. Soil parameters.

filed monitoring system requires long range power efficient communication solution to be able to monitor large agricultural field for long duration. For that the LoRa is the best suited technology as it offers long-range, good power efficiency, and is scalable. For processing unit at soil sensor node, Arduino is used being an open source and low cost. To test the system developed, two such wireless soil sensor nodes are developed. Fig. 22 shows the developed wireless soil sensor node, with all elements and the node being deployed in the field.

The weather station, is the central unit of the system for Precision Irrigation, collects the local weather information and information from wireless soil sensor nodes via LoRa communication channel between the soil sensor node and weather station. Each wireless sensor soil node is identified with the specific address and the same can be used to map soil condition with physical location of farmland. In LoRa communication, wireless soil sensor nods behave as transmitter and weather station with LoRa module acts as receiver. After collecting the weather and soil conditions, the weather station uploads the information to the Thingspeak IoT cloud. The weather parameters gathered by the weather stations are air temperature, relative humidity, wind speed, and wind direction. Fig. 23 gives the lab setup of the weather station and weather station installed for the testing is shown in Fig. 24. Weather station deploys open-source processing unit with WiFi capable of uploading information to IoT cloud.

The third and final elements for the developed system are IoT cloud and end-user monitoring devices. Thingspeak IoT cloud in addition to providing a means of monitoring the agricultural field conditions also facilitates in storing of a huge amount of agricultural data and also makes the data available globally for further analysis and research. The end- user monitoring device is normally a mobile phone installed with an application or laptop. Uses can monitor the field conditions at any point of time by logging the application providing an assistant to the farmer to take the appropriate decisions at the correct time. The system was tested with two soil sensor nodes and the system was able to successfully uploads the information to the selected IoT cloud. The Thingspeak data visualization of soil sensor for node 1 and sensor node 2, for internet browser, along with weather parameters is shown in Fig. 25 and Fig. 26 respectively. Internet browser can be of any laptop or mobile phone. But the disadvantage of using the internet browser is each time the user needs to follow a long process of login, selecting a channel, and may not be a familiar interface for farmers. With the android mobile app anyone can easily monitor the farmland conditions with only back and select commands. Only requirement is to install the android app and register all the required Thingspeak IoT cloud channels in the app only for once. Mobile interface for dashboard and field monitoring is shown in Fig. 27.

The weather and soil parameters when plotted together shows a close correlation between them as provided in Fig. 28 and Fig. 29. The relationship between air temperature with soil moisture and relative humidity with soil moisture is plotted in Fig. 30 and Fig. 31 respectively. From the visual inspection of Figs. 30 and 31, it can be deduced that soil moisture follows both the air temperature and relative humidity. The crossing of the air temperature and soil moisture graph is expected because in the daytime air temperature rises quickly but due to the water holding capacity of the soil, the same abrupt change in the soil moisture is not expected. A similar type of observation is available from Fig. 31 for relative humidity and soil moisture content. But both the graphs show that soil moisture content is somewhat dependent upon air temperature as well as on relative humidity. The relationship between soil moisture with air temperature, relative humidity, and soil temperature is collectively plotted and shown in Fig. 32.

Urban farming and associated landscape need to be integral part of

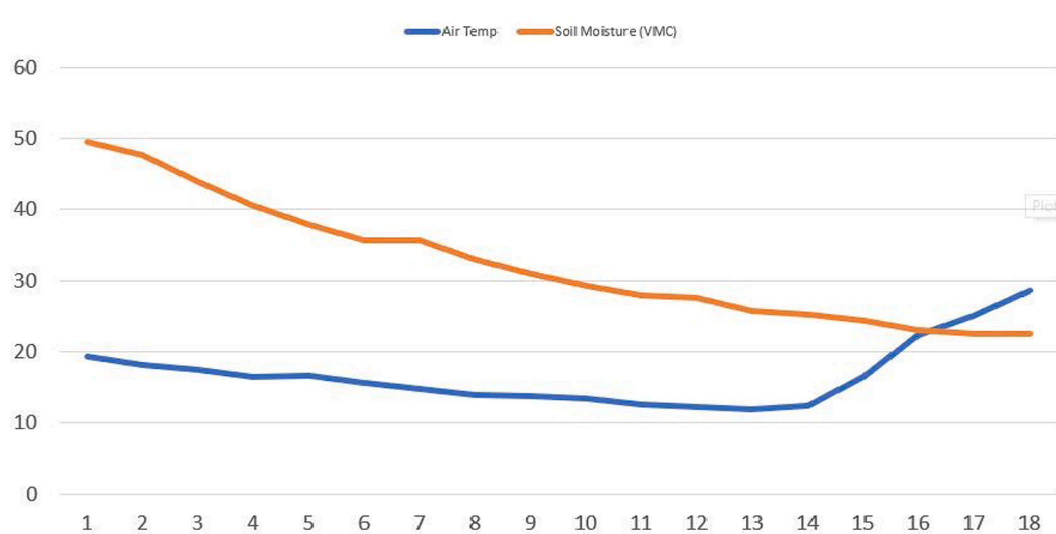

Fig. 30. Air temperature and soil moisture.

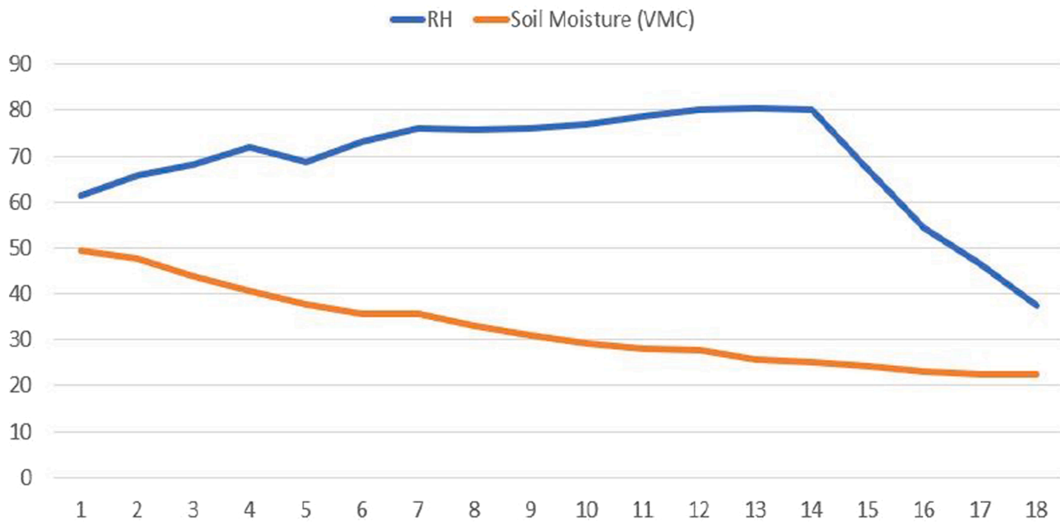

Fig. 31. Relative humidity and soil moisture.

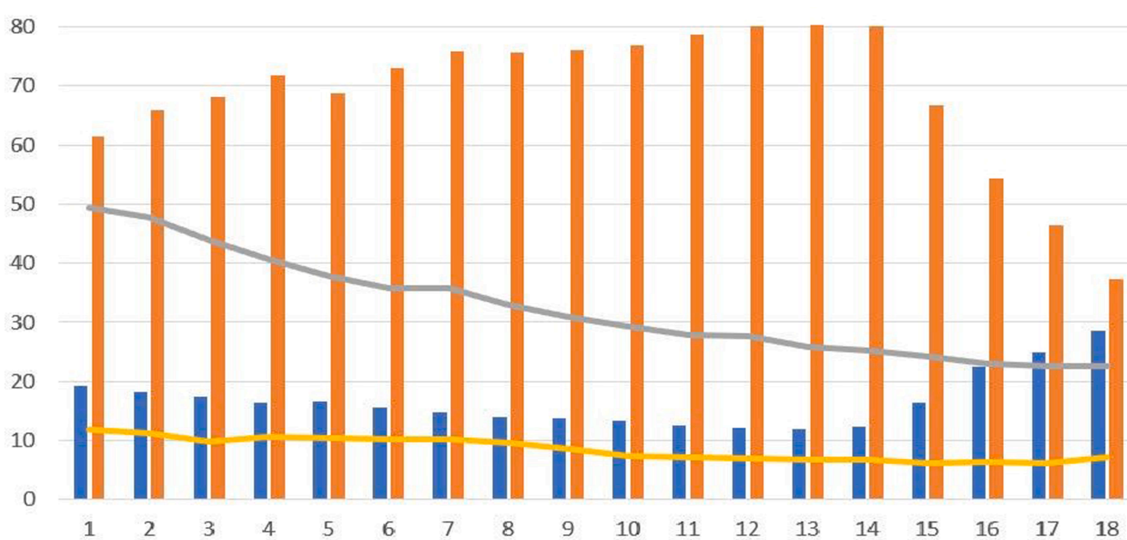

Fig. 32. Soil moisture distribution in urban locations.

Fig. 33. Soil moisture distribution in urban elds.

smart city, as they provide sustainability to life in cities. In city planning, landscape locations are required to be located in such a way that they have positive impact of city's environment with minimal resource utilization. The quota for the irrigation and domestic water needs be allocated properly to support life in cities and motivate farmers to adopt advanced irrigation practices for better efficiency.

Urban farming may consist of concrete or cemented boundaries or establishments in or around farmland. One of the observations with the presence of such establishments is that the soil moisture around such structures is more prone to gets lower down in comparison to soil's moisture in the farm area away from such structures. Fig. 33 shows the comparison of soil moisture near the concrete areas is much low, in images 1 and 3 of Fig. 33, in comparison to field section away from such structures image 2 in Fig. 33. From this observation, the soil sensor node density needs to be increased if any part of the field is followed by the concrete wall and any such structure in comparison to the number of a soil sensor node to be deployed in field area away from such structures for appropriate irrigation planning and need to be adaptive as per measured soil moisture values. Possibly, planting at such a location may be avoided.

Although while searching for the research in Precision Irrigation from Society 5.0 or smart city perspective, very little or almost no literature is available but there are many systems developed for irrigation monitoring and control under Precision Agriculture concept. Table 4 compares the available state-of-the-art implementations for Precision Irrigation planning with the system presented in this research

Table 4
Comparison of developed system with state-of-the-art implementations on technical aspect.

S. No.	Challenges	Irrigation automation based on IoT, cloud, and LPWAN in (Kamienski et al., 2019; Ali et al., 2019; Davcev et al., 2018; Cambra et al., 2017; Keswani et al., 2019)	Irrigation Automation with Zigbee (Azaza et al., 2016; Kim and Evans, 2009; Hong and Hsieh, 2016)	Irrigation Automation using Bluetooth (Gutierrez et al., 2014; Rao and Sridhar, 2018; Salvi et al., 2017; Rajkumar et al., 2017; Jawad et al., 2017)	Proposed system for Precision Irrigation
1	Urban Farming	Not considered	Not considered	Not considered	Considered
2	Scalability	Scalable	Scalable	Not scalable	Scalable
3	Communication Range	Upto 1000 m	Upto 100 m	Upto 10 m	Upto 8000 m
4	Weather Conditions (wind direction, air temperature, and relative humidity)	One or the other weather not considered	One or the other weather not considered	One or the other weather not considered	Considers, air temperature, relative humidity, and wind conditions
5	Soil Conditions (Soil Temperature)	Mainly focused on soil moisture measurement	Mainly focused on soil moisture measurement	Mainly focused on soil moisture measurement	Considered, soil VMC and soil temperature

Table 5
Weather station with respect to previous arts.

Reference/Year	Parameters	Technologies	Processing unit	Data Visualization	Improvement in Proposed system
(Sarkar et al., 2020)/2020	Temperature Precipitation Wind speed Wind direction	Wi-Fi Fog computing Cloud computing Mess network	NodeMCU	Information to different devices	The proposed system is an IoT enable standalone low-cost weather station. It has a relative humidity sensor which is missing in (Sarkar et al., 2020), an important parameter to understand the weather. Uploads data to freeware IoT cloud Thinkspeak, which makes it cost affective and easy for monitoring.
(Marwa et al., 2020)/2020	Temperature Humidity Rain	LTE Zigbee	Not mentioned	HTML based web page	The proposed work considers all the important weather parameters like wind conditions and uses free IoT cloud Thinkspeak for data storage, visualization, and monitoring using low-cost IoT processing open-source board
(Kapoor and Barbhuiya, 2019)/2019	Temperature Humidity Rain Wind speed Wind direction	MQTT Wi-Fi	Raspberry Pi Raspberry Pi zero Arduino	AWS Web application based on Django framework	A low-cost IoT board is used to upload data on the IoT Thingspeak IoT class, which does not have any service charge up to minimum channels.
(El-magrous et al., 2019)/2019	Temperature Humidity Solar radiation Wind speed Wind direction	SD card Wi-Fi	Arduino Mega	Mobile application	No local display and storage media The proposed system does not have any local display and data storage device, making it power efficient and cost effective. Uploading data on IoT Thingspeak cloud makes data available for research and understanding the pattern and influence of weather and soil conditions on soil moisture. NodeMCU, a low-cost IoT board is used for local processing and IoT connectivity.

article for the different technological aspects. Many of the works of literature referred in Table 4 somewhere fail to implement all the important and non-redundant weather parameters, wind speed, wind direction, air temperature, and relative humidity, as even missing the wind speed or direction parameter may not give a proper understanding of the weather conditions. Similarly, for the soil conditions, most of the literature fails to address the soil temperature which is an important factor in agricultural activities planning. For IoT connectivity, few of the mentioned references do have IoT connectivity with desktop or nay such complex system which is quite an infeasible solution for agricultural applications. Even if the IoT solutions provided are based on the latest developed technologies fails to come up with the overall monitoring solution for agricultural parameters for field monitoring.

The system presented in this article employs LoRa communication technology which makes the system scalable, power efficient, and capable to communicate at long range with IoT-driven real-time data monitoring solution for Precision Irrigation. Overall, the present system tries to address the shortcoming or research gap left in the earlier proposed solution, by considering their impact on the overall agricultural yield.

The system presented in this article has a central and the most important element i.e., weather station. The weather station collects all the soil-related information and gathers the information for weather conditions and uploads both the information to the IoT Thingspeak cloud for monitoring and makes the data globally available for data analysis. Although the overall system attempts to fill the research gap in Precision Irrigation systems by providing a more advanced and easy-to-use solution. Table 5 gives the various aspects in which the weather station developed for the system is an improved version over the previously available weather stations.

Credit author statement

Rajeev Sobti: Idea generation and conceptualization, Methodology, Draft manuscript editing, Assistance in programming.

Dushyant Kumar Singh: System implementation and testing, Data collection, Writing- Original draft preparation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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