Chapter 1
Issues and Challenges of Groundwater and Surface Water Management in Semi-Arid Regions

Khadeeja Priyan

Contents

1.1 Introduction

Water is an essential natural resource for survival and ecological development on Earth. Currently, all countries face surface water and groundwater problems, especially in semi-arid regions; these problems include water pollution, groundwater changes, lack of rainfall, declining agricultural production, and climate change–related factors (Pande et al. 2018a). Water is a scarce and, hence, precious resource as a result of human population expansion, industrialization, urbanization, and increased irrigated agriculture. Agriculture is the largest user of groundwater and surface water, but in the future other factors will place greater demands on water in

K. Priyan (✉)
Civil Engineering Department, G H Patel College of Engineering and Technology, Vallabh Vidyanagar, Gujarat, India
e-mail: khadeejapriyan@gcet.ac.in

C. B. Pande, K. N. Moharir (eds.), *Groundwater Resources Development and Planning in the Semi-Arid Region*, https://doi.org/10.1007/978-3-030-68124-1_1

semi-arid areas (Seckler et al. 1998), and water resources for agriculture will be overused or underused (Tanji and Kielen 2002). India has more than 17% of the world's population but only 4% of its water resources and 2.5% of its land resources. According to Nitiayog data, 20.92% of the population in India lives below the poverty line. Over the years, the demand for water has been increasing manyfold in various sectors, such as agriculture, domestic consumption, industry, and power generation as the population has increased. The demand for freshwater is increasing due to rapid and unplanned urbanization and economic growth (Sahasranaman and Arijit 2018). Since water is a precious resource in agriculture, every drop of water available for irrigation is significant for overall farming efficiency. Due to the challenges in groundwater and surface water resources, Indian agriculture faces water scarcity. Over the years, agricultural output in India has become less remunerative and more uncertain. This chapter discusses various issues and challenges connected to groundwater resources and planning in semi-arid regions.

Water is a common pooled resource that can be managed only when all stakeholders, such as residents, civil society and government, or a combination of all these, understand its importance as a common resource (water portal, 2020). The various governments involved are trying to implement sustainable water management policies. These policies mainly aim at the development and management of sustainable water resources. Several studies have looked at local demand and supply situations. Molden et al.'s (2001) investigation was based on various water-scarcity studies around the world. It classified water-scarcity areas into three categories: (1) water-scarce areas, (2) high potential areas, and (3) high need areas. Based on this classification, physical water scarcity is experienced in water-scarce areas, water logging and salinity problems are found in high potential areas, and water scarcity with respect to economic, financial, and skilled human resources is found in high need areas. Hence, there is no universal solution to global water crises. However, owing to large special and temporal variations, many regions experience water scarcity. Water-scarce regions lack adequate clean water to meet human drinking water and sanitation needs. This impacts human health, productivity, the environment, and ecosystems (Cosgrove and Loucks 2015). Growth in irrigated agriculture poses a serious threat to the environment in many places around the globe (Abdullaev 2004).

It has been estimated that the global supply of available water is more than sufficient to meet current and foreseeable demand in the world (Molden et al. 2001; Cosgrove and Loucks 2015). Its spatial and temporal distribution across the globe varies. About 60% of the annual precipitation on the Earth's surface, 108,000 km^3, evaporates into the atmosphere and the remaining flows towards the sea, of which about 20–25% could be managed effectively (Seckler et al. 1998). Freshwater requires meeting demand for domestic, economic development, and environmental needs. The available resources are inadequate in many parts of the world to meet these needs (Cosgrove and Loucks 2015).

Aquifers are vulnerable to pollution through porous media or through fractures or cavities. In urban areas, the presence of microorganisms poses a threat to the quality of drinking water. Owing to intense agricultural activities and industrialization, contaminated water flows increasingly through subsurface layers into groundwater. Surface water resources are under stress due to the declining potential for augmenting existing supplies and the pollution of freshwater resources from domestic and industrial wastes. Efficient and effective water management techniques are of paramount importance for groundwater sustainability. All governments have initiated flagship programmes to implement sustainable water management programmes.

Demand for water continues to increase due to population growth, industrialization, and urbanization. As the supply of water decreases, increasing competition and growing conflicts between these sectors pose a significant threat to water management. Hence, water management needs to address the balance between water demand and supply. Semi-arid regions are categorized according to whether they are in developed or underdeveloped countries, but the bottom line is that they are regions which receive little rainfall in a given year. Although this may seem like an ideal scenario, the drawbacks of semi-arid regions stem from the unreliability of water availability throughout the year. Water is a scarce economic commodity, and climate change affects both special and temporal variability. Groundwater or subsurface water is defined as the total water found beneath the surface of the ground and is considered part of the hydrologic cycle (Fig. 1.1). This chapter discusses the issues and challenges of water management (both groundwater and surface water) on both the supply and demand sides in the face of climate change. The study mainly highlights the issues and challenges faced in semi-arid regions in India, as well as

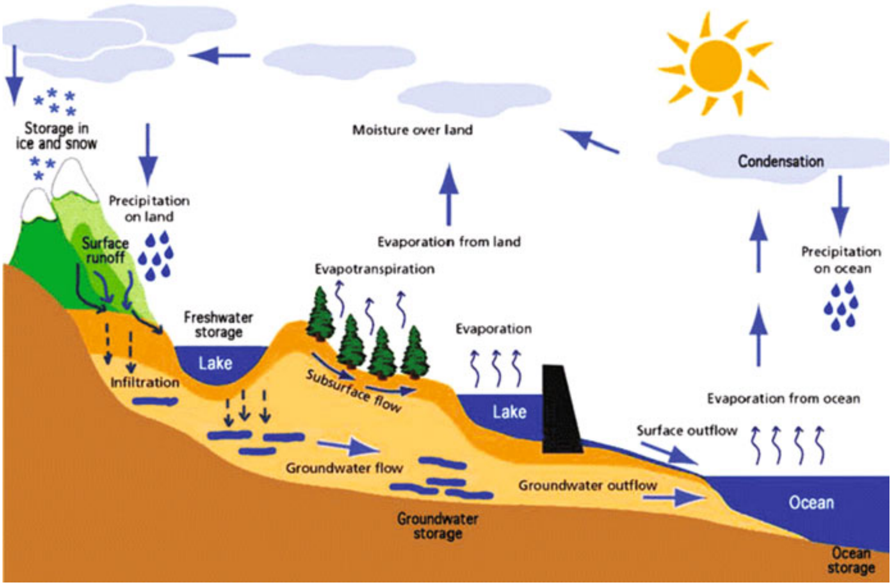

Fig. 1.1 Schematic diagram of hydrologic cycle

initiatives taken by the country for sustainable development. It also focuses on the scope and limitations of supply- and demand-side approaches to water management.

1.2 Semi-Arid Regions

Water is a precious natural resource which is severely stressed in many parts of the world. Because water scarcity is a major concern in many semi-arid regions lacking perennial sources of water, managing the available usable water is crucial. Generally, these regions experience water scarcity due to low levels of rainfall and high evapotranspiration rates, and they face drought, low precipitation, and acute water shortages. Since the late nineteenth century, large-scale irrigation has been practised in many arid and semi-arid regions (Tanji and Kielen 2002; Pande and Moharir 2015). Groundwater is a reliable source of water in arid and semi-arid regions and has been widely consumed for irrigation, domestic, and industrial uses. Exhaustive water abstraction has led to aquifer overexploitation and resulted in a lowering of the water table at alarming rates. The northern and western parts of Gujarat state are semi-arid regions in India. These regions experience highly erratic rainfall with very high evaporation rates. The percolation of water to the groundwater table takes place mainly through fractures and fissures present in hard rock, which leads to a deep water table. All rivers are seasonal rivers. Stream orders were identified in between 1–6. Groundwater in key aquifers is rapidly depleted, which results in the degradation of aquifers. Generally, the upper reaches of river basins in semi-arid regions contain steep topographic gradients, which cause high runoff. The groundwater recharge potential is very low because of insufficient rainfall, watershed planning, and low storage capcity. Many semi-arid areas have compact and fissured rocks and the aquifers results under the moderate water yield potential. The lower reaches of semi-arid regions have good groundwater potential, but they also suffer from salinity problems.

1.3 Water Scarcity

Water is a scarce economic commodity. Since water shortage is experienced in different seasons, augmentation techniques are adopted on both the supply and demand sides of water management. As challenges in water development and management increase, the quality and quantity of freshwater are also affected. Many of the world's watershed areas and river basins are overexploited and in a state of chronic water stress. The permanent depletion of groundwater resources could have severe consequences with associated environmental impacts. It has also been observed that in coastal areas, due to excessive pumping and deepening of aquifers, freshwater aquifers have been contaminated by sea water. Rapid urbanization and land-use changes have resulted in reductions in the natural infiltration or recharge of aquifers. Similarly, in inland regions, especially alluvial areas, irrigation with high total dissolved solids from deep aquifers causes land degradation. In hard-rock areas of Saurashtra, excessive pumping has led to the drying up of wells and acute shortages of water for drinking and irrigation purposes (Kumar 2001; Khadri and Moharir 2016). There is thus an urgent need to augment valuable water resources, i.e., groundwater and surface water resources. This has led to various problems related to the quantity and quality of water and issues such as the deterioration of surface water quality, water levels, and the depletion of groundwater sources. A realistic approach to water management takes into consideration social and economic aspects. Freshwater demand in the world doubles every 21 years. To achieve effective utilization of available water resources, Keller et al. (1996) observed discharges could be captured effectively to meet demand growth in basin area.

1.4 Climate Change and Impact of Floods and Droughts

Climate change has significant negative impacts that pose a major economic threat in the world that will last into the next decade (CSE 2020). According to the CSE's report, the top risk in the past 4 years stemmed from extreme weather events, and the failure of climate change mitigation and adaptation will have a huge impact on the global economy. In 2019, around 2359 per 100,000 people were affected by climate change disasters. Most Indian cities are vulnerable to flooding in monsoon months due to the non-availability of proper stormwater management systems. According to the 2011 census, Indian cities are home to 31% of the total population and their GDP contribution is 63%. It is estimated that by 2030, India's urban population will become 40% of the total with a GDP contribution of 75%. This may result in a huge demand for urban infrastructure. Urban growth development often results in an uncontrolled rise in peak flood hydrographs. Hence, stormwater management poses a significant challenge for urban developers like civic authorities, consultants, and landowners. Innovative stormwater management techniques are essential to solve the problems associated with this challenge, such as reduced groundwater recharge, which leads to a lowering of the groundwater table at an alarming rate and environmental pollution. Water is considered the first line of defence against climate change (water portal, April 2020). People experience difficulty on a daily basis accessing water due to climate change. The water crisis can be tackled by judicious utilization of this precious resource by promoting water conservation and sustainable water-use techniques. Water quality management should be effectively integrating by wastewater treatment systems. Sahasranaman and Arijit (2018) argue that 'clean India' and 'Swachh Bharat' campaign will be successful if proper sanitation measures are implemented successfully.

Many cities have conventional stormwater practices in the form of drainage through sewers. However, all smart city proposals emphasize above all landscape development. Proposals incorporate the need for rainwater harvesting and stormwater management for reuse and conserved water in aquifers (www.smartcities.gov.in). Low impact development (LID) for stormwater management is an innovative initiative of green infrastructure that originated in 1990 to mitigate climate change and pollution control. Green infrastructure ensures the sustainable management of limited open spaces available in urban areas and provides a good opportunity for developing and preserving urban landscapes. This strategy uses various techniques to mitigate the impact of increased urban stormwater runoff near the sources and brings certain ecological advantages. It includes different site design strategies which will be helpful for better hydrological components, for example infiltration, evapotranspiration, filtration, harvesting, and retention. This will be helpful in controlling flooding resulting from improper stormwater management. The hydrological impacts of LID are peak discharge control, improved groundwater infiltration, and improved evapotranspiration.

Various structural and non-structural best management practices (BMPs) have been studied, and these practices have been adopted in the USA, Canada, UK, and other countries. Landscape-based LID techniques, in the form of, for example, green roofs, rainwater harvesting, grass swales and dry swales, bioretention, permeable pavement, perforated pipe systems, and soakaways, have been designed and adopted in various countries. Bioretention or raingardens have been adopted as an effective BMP in the USA (Davis et al. 2009). Bioretention is an effective method whereby all the physical, chemical, and biological processes of a natural hydrologic system are performed. The quality of infiltrated water will improve once it passes through different porous soil media. Bioretention is one of the popular stormwater management practices for addressing urban non-point pollution in New England (Dehais 2011).

1.5 Issues and Challenges of Groundwater Management

Groundwater recharge of rainwater through soil contributes to the rise of the groundwater table and is a reliable source of water in semi-arid regions. Groundwater caters to the demand of the country's ever-growing domestic, agricultural, and industrial sectors and is extensively exploited by various users. The accumulation of groundwater also happens from recharge brought about by seepage losses from irrigation networks and deep percolation from farm irrigation (Tanji and Kielen 2002). Irrigation through all sources has contributed significantly to agricultural production in arid and semi-arid regions. Because rivers are seasonal in these regions, groundwater is the only dependable source of water. Wells are observed in many parts of semi-arid regions, especially on the upstream sides of the river basins located in semi-arid regions. Large seasonal drops in groundwater levels are observed in these regions, which face acute water issues, in terms of both quantity and quality (Pande et al. 2019a; Moharir et al. 2019).

India's irrigation agriculture has two components: (1) surface (canal) irrigation development and (2) groundwater resource development. Surface (canal) irrigation development requires high public investment by the states, whereas groundwater resource development involves private tube well development. The share of groundwater sources for irrigation has increased from 28.7% (1950–1951) to 62.4% (2012–2013), but the share of canals in net irrigated areas has decreased from 39.8 to 23.6%.

The mechanized pumping technologies which emerged in the mid-twentieth century caused widespread drawdown externalities, and this resulted in the overdevelopment of groundwater resources, which led to the depletion of shallow aquifers (FAO 2003). The increased application of engineering approaches is a viable way to achieve economic returns in water productivity. Raising the physical productivity of water in crops without due consideration to economics will have little relevance for small farmers in developing countries (Kumar and Van Dam 2013, b).

1.5.1 Overexploitation of Groundwater Sources

Perennial sources of surface water are not available in most semi-arid regions. The groundwater table declines when discharge is higher than recharge. Deeper water levels are observed in overexploited parts of semi-arid regions. Deep confined aquifers, which are grouped into, first, aquifers whose depth varies from 78 m below groundwater level (bgl) and, second, aquifers varying from 154 to 274 m bgl, which existin in North Gujarat (CGWB 2018). According to the CGWB report, steep declines have been noticed during the last 5 years in North Gujarat. The groundwater level is declining at an average rate of 2 m per year in deeper aquifers. Two distinct hydrogeological rock units, such as hard rock and soft rock, have been identified (Khadri and Pande 2016b)

The scale and rate of abstraction due to massive expansion in pumping capacity and the rate of groundwater level decline have made the aquifer system vulnerable to overabstraction. Groundwater recharge and conservation programmes are needed in the Saurashtra, North Gujarat, and Kachchh regions. In these areas, groundwater recharge through artificial recharging techniques should be enhanced. Irrigation is the single largest user of water, accounting for more than 70% of the world's supplies of developed water (Seckler et al. 1998). The negative impacts of groundwater exploitation include (1) a declining groundwater level, (2) groundwater contamination, (3) decreased crop yields, (4) land subsidence, and (5) a reduction in environmental flows (Khadri and Pande 2016a; Patode et al. 2016).

FAO (2003) identifies the following consequences of groundwater exploitation:

- Changes in flow patterns in nearby aquifers;
- Reduction in water usage for ecological purposes, such as base flows in streams and wetlands, and damage to ecosystems and downstream users;
- Increased pumping costs and energy usage;
- Land subsidence and damage to surface infrastructure.

1.5.1.1 Declining Groundwater Tables

Due to the mechanized pumping technologies which emerged in the mid-twentieth century, widespread drawdown externalities have occurred, resulting in the depletion of shallow aquifers (FAO 2003). Groundwater levels have declined at an alarming rate, and proper control measures and planning should be put in place to conserve water in aquifers. Adequate augmentation of groundwater recharge schemes should be implemented through artificial recharging methods.

1.5.1.2 Pollution in Aquifers

Degradation of aquifers is caused mainly by the disposal of human and industrial waste and the percolation of pesticides and herbicides. Aquifers are vulnerable to pollution through porous media or fractures/cavities (Moharir et al. 2020). Generally, the quality of deep aquifers is better than that of shallow aquifers. In subsurface layers, bacteria can survive up to 50 days, but a virus can survive for longer. In urban areas, the presence of microorganisms is a threat to the quality of drinking water. Due to intensified agricultural activities and industrialization, contaminated water flows are increasingly finding their way to subsurface layers and into groundwater (Moharir et al. 2017; Khadri and Moharir 2016; Pande et al. 2018b).

Sources of pollution:

- Agricultural pollution
  - Extensive use of agricultural chemicals
  - Non-point sources pollution, predominantly in agriculture rather than industry and municipal sewage systems as large coverage of area.
  - Fertilizer
  - Nitrate concentration (Gujarat) and other nutrient pollution
  - Extensive irrigation
- Urban pollution
  - Leaking sewers and other wastewater sources
  - Urban flooding
  - Construction materials
  - Domestic wastewater disposal

Impact of groundwater pollution:

- Water-borne diseases, e.g. cholera
- Pollution externalities
- Major causes of groundwater contamination

1.6 Sustainable Water Management

India faces challenges in achieving 9 out of 17 sustainable development goals (CSE 2020). There is a need to develop strategies to reduce water stresses. Al-Jawad et al. (2019) suggested through their modelling approach in the Diyala River Basin in Iraq that to achieve sustainability within the next 25 years, strategies need to be developed to reduce water stresses by 45%. Sustainable Development Goals (SDGs) use various indicators for water resource management. These indicators are source augmentation and restoration of water bodies, source augmentation (groundwater), large- and medium-scale irrigation (supply-side management), watershed development (supply-side management), participatory irrigation practices (demand-side management), sustainable on-farm water use practices (demand-side management), rural drinking water, urban water supply and sanitation, and policy and governance. With respect to these indicators, Gujarat ranks first, with 7.5 points. The country average is 4.52 and the water metric includes surface water and groundwater (Pande et al. 2017).

1.7 Challenges for Sustainable Groundwater Management

Because India is an agrarian country, the present and future challenges of sustainable agricultural demand can be met by technological innovation. To improve crop productivity, efficient irrigation techniques are needed to raise yield production. Over the years it has been seen that Indian agriculture is beset with water scarcity and has become less profitable and more uncertain. Hence, there is a prudent and urgent need to use available water efficiently; micro-irrigation is one innovative technology that holds great promise in terms of raising crop yields. Because land and water are basic needs in the agricultural and economic development of any country, 70% of India's population is dependent on agriculture for their livelihood. Gujarat has many hectares of unused cultivable land (Pande and Moharir 2018).

Timplementation of sustainable groundwater management faces several challenges. For sustainable groundwater management, adequate scientific data are required on the following matters: (1) Annual water balance of recharge and abstraction; (2) inter-annual variability of replenished water through recharge since variability is very high; (3) reliability and productivity of wells in terms of water levels and water quantity and quality; (4) availability of reliable time-series data of groundwater level in specific aquifers; (5) quantifying aquifer recharges; (6) sustainability of socio-economic activities in relation to falling groundwater levels, which is complex; (7) groundwater overdraft and declining quality; (8) groundwater pollution, including urban wastewater discharges and industrial pollution; (9) overstressing of local aquifers in urban areas—struggling to maintain water quality; (10) groundwater pollution from agricultural chemicals; (11) cost of pollution control and aquifer remediation; (12) salinity and waterlogging; (13) deaths related to water pollution; (14) soil and groundwater contamination due to industrialization and population growth; (15) patterns and management of groundwater use—socio-economic development, urban vs. rural use, including irrigated agriculture; (16) decision-making framework; (17) assessment system; and (18) long-term effects of climate change and global warming. The sustainable yield of an aquifer must be estimated to determine the nature and variability of aquifer recharge, quality of recharge water, control of aquifer degradation, techniques to enhance recharge, and patterns and intensity of groundwater use. Some of these data are technical, whereas others are socio-economic in nature. Scientists and researchers should give priority to both these types of data if they wish to obtain reliable and accurate results (Pande 2020a).

A good assessment system is required to determine groundwater availability and productivity. Legislation should be put in place to prevent unauthorized drilling or deepening of wells and pumping of water. At the farm level, low-flow irrigation networks are required for sustainability water conservation. Micro-irrigation techniques, such as drip irrigation, sprinkler irrigation, and others, are common methods used in precision farming and sustainable agriculture development (Pande 2020c). This techniques can be adopted by farmers. This methods can be reduce loss of water during irrigation. To reduce evaporation loss from the soil using this method, mulching can also be used. This can help to improve crop yields and optimize water use. Usually plastic mulches are used, but their disposal is very harmful. Micro-irrigation techniques have advantages and disadvantages. Its advantages are as follows: (1) water application efficiency is high; (2) fields with irregular shapes can be easily irrigated; (3) recycled non-potable water can be safely used; (4) soil type plays a less important role in the frequency of irrigation; (5) fertilizer application efficiency is high because it can be mixed with water before application; (6) soil erosion is reduced; (7) weed growth is controlled; (8) water distribution efficiency is highly uniform, controlled by the output of each nozzle; (9) labour costs are lower than other irrigation methods; (10) variation in supply can be managed by regulating valves and drippers; and (11) it is usually performed at lower pressure than other types of pressurized irrigation, reducing energy costs (Pande 2020d).

Drip irrigation's disadvantages are as follows: (1) the initial costs can be more than those of overhead systems; (2) the pipes should be clogged and the water is not properly filtered by equipment; (3) water, time, and harvests will be wasted if the system is not installed properly; and (4) the all PVC pipes often suffer from rodent damage, requiring the replacement of the entire pipes and increasing expenses. These systems require careful study of all the relevant factors, like topography, soil, water, crop and agro-climatic conditions, and the suitability of a drip irrigation system and its components.

Though technology holds great promise and benefits, according to the report published by IAI et al. (2016), the national schemes initiated since 2006 have not addressed the following important issues related to planning and implementation of the technology: (1) inadequate focus on nationwide spread of micro-irrigation technology; (2) inefficiency in implementation as the responsible agency changed it from a dedicated programme to a component part of National Mission For

Sustainable Agriculture (NMSA) under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). In many states, allocated funds were not used properly due to a lack of implementation strategy; (3) lack of reliable guidelines and delay in government orders; (4) unavailability of subsidy funds for installation as subsidies reduced from 50% to 35% and the allocation of funds under various schemes was cut; and (5) the very difficult for securing the financial support by financial services and banks. It was reported that a lower adoption rate was due to budget cuts during the period 2013–2016.

Meti (2012) conducted a study on bananas in Dharwad, Karnaka, and stated the various constraints of adopting drip irrigation: (1) complicated loan application process and delays in receiving the funds, (2) non-availability of soluble fertilizers, (3) inadequate supply of electricity, (4) high capital investments, (5) inadequate follow-up services by drip agencies, and (6) non-availability of quality materials and damage to laterals by rodents. The policy and implementation strategies should be revised for better penetration of this technology.

The noted benefits due to micro-irrigation technology are increases in yield, improvement in water use efficiency, reduction in the cost of water, fertilizers, and manure, and weed removal. All these add up to an increase in the overall economic benefits from the optimum use of water since the technology offers greater benefits like irrigation efficiency (50–90%), fertilizer (28.5%), and energy (30.5%) (IAI 2016). This technology is highly relevant and praiseworthy. Micro-irrigation is an intervention that can address various issues of agricultural growth and hence is considered a technology that can be leveraged to achieve sustainable agriculture. Farmers have been adopted the advanced technology for farming and then farmers income is increased due to technology in in any areas. Hence economic considerations can be incorporated into engineering approaches to emphasize the importance of water productivity.

Real water savings can be realized from irrigation efficiency at the field level. To improve water productivity in agriculture, initiatives can be taken at the field level and the saved water can be used for the irrigation of additional acreage or for environmental and social needs. Kumar et al. (2008) proposed various factors, such as type of crop and spacing between them, type of micro-irrigation technology, soil type, climate, and geo-hydrology, in real water savings through the use of micro-irrigation technologies (Khadri et al. 2013).

In India, if an agricultural area under irrigation is less than or equal to 30% of the net sown area, it is referred to as a rainfed area, and if more than 30%, it is an irrigated area. Massive public investments have been made, mainly in watershed development and management, to improve rainfed agriculture using irrigation structures. However, the interventions in rainfed areas have had limited success due to lower levels of rainfall and to the aridity. Hence proper interventions are required based on the agro-ecology and hydro-meteorology of the region (Kumar et al. 2017). Reliable and adequate water supply and water delivery control can increase water productivity at the farm level and lead to real water savings. The benefits of micro-irrigation technology are increased yield, improvement in water use efficiency, reduction in the cost of water, fertilizers, and manure, and weed removal. All these add up to an increase in the overall economic benefits from the optimum use of water. The real water savings from the use of micro-irrigation technologies mainly stem from savings from non-beneficial evaporation and non-recoverable deep percolation. Hence the water efficiency due to real water savings is very different from the savings in applied water (notional water saving).

The present chapter is to appraise drip irrigation with mulching as an innovative technology for sustainable agriculture in India and its significant impact on water productivity and land productivity. Various studies are available on the effect of drip irrigation and mulching on different crops (Tiwari et al. 2014; Biswas et al. 2015). These studies provide benefits in terms of yield increase, economic returns, and water use efficiency in connection with applied water. But real water savings are not discussed in existing studies. This chapter assesses the current status and technologies of micro-irrigation and evaluates the future prospects of micro-irrigation adoption in India. Drip irrigation has delivered many benefits with respect to water resource utilization as well as overall economic value. The yield from mulched treatments for all levels of water application are considerably higher than non-mulched treatments (GOI 2005; National Water Policy 2012; Moharir et al. 2020).

SDGs use various indicators for water resource management. These indicators include source augmentation and restoration of water bodies, source augmentation (groundwater), large- and medium-scale irrigation (supply-side management), watershed development (supply-side management), participatory irrigation practices (demand-side management), sustainable on-farm water use practices (demand-side management), rural drinking water, urban water supply and sanitation, and policy and governance. Gujarat ranks first on these indicators with 7.5 points. The country average is 4.52 and the water metric includes surface water and groundwater (CSE 2020).

1.8 Challenges in Surface Water Sources

Many large water projects exist in various parts of the world. Large dams cause various environmental and ecological problems. Large-scale land submergence leads to the need for rehabilitation and resettlement of people, loss of valuable ecosystems, prevention of ecological flows of water at the downstream of the dams, and loss of flora and fauna downstream, for example. Reservoir siltation and soil erosion are other major problems that arise in connection with large-scale surface water projects. Other impacts include soil salinization, declining ecological flows, and land subsidence, for example (Pande et al. 2019b).

Over the past few decades, extreme flood events have become more frequent due to the effects of urbanization and climate change. This has caused even the most well-planned drainage systems to be inefficient in performing their functions. Flood risk management, computation of flood water contamination with sewage water, and analysis of extreme flood events are some of the critical areas to be evaluated.

Conventional drainage systems focus on removing excess stormwater from drainage basins as quickly as possible. However, due to recent changes in climate and an increased requirement of water quantity as a result of population growth, drainage systems should be designed such that water can be collected, stored, and used for other purposes. Current drainage systems should be analysed, evaluated for their performance during monsoons, and modified with the help of recent technologies, case studies, and software in the most cost-effective way (Pande 2020b).

Due to increased urbanization, permanent road surfaces, existing buildings, and pavements are causing decreases in the percolation of water into soil. This is due to the fact that pucca road surfaces and other infrastructures will not allow water to permeate materials, leading to the requirement of drainage lines on the sides of roads. Because water must be carried by drainage lines, attempts have been made to carry large quantities of water away from streets such that the water does not remain on surfaces for a long time and hinder traffic and other activities. In this scenario, water tries to quickly escape a given area without taking into account the necessity of maintaining groundwater levels for the use of bore wells, recreational activities, and other uses. Many countries have devised solutions involving low-impact development for stormwater management, a stormwater management technique that aims to manage runoff water using distributed and decentralized micro-scale controls (Khadri and Pande 2015).

Floods have many causes, including heavy rainfall, unusually high tides, tsunamis, and failure of hydraulic structures, for example. Periodic floods occur in many Indian rivers due to heavy rainfall in catchment areas. Flood plains exist on most of the major rivers in India, which can cause large-scale damage to property and crops. Waterlogged and poorly drained areas are the worst affected. Tanji and Kielen (2002) showed that a very high rising water table results in water logging and associated salinity problems. In conventional drainage systems, less importance is given to water quality, services, and recreational uses. Moreover, conventional drainage systems have limited capacity and constraints that make them inflexible. Contemporary requirements for urban stormwater management relate to runoff quality, esthetics, recreational value, environmental protection, and a variety of water uses. Hence, an integrated and transdisciplinary approach will be necessary to take into account these various factors in a common platform to facilitate innovative and sustainable solutions. A combination of centralized and decentralized systems will also be necessary to combine the best of the different systems and enhance their synergy for sustainable design. To achieve these goals, a design framework integrating technical, social, environmental, economic, legal, and institutional aspects will be crucial. Stormwater should be treated as a positive source in sustainable drainage systems. Despite advancements in techniques and tools for sustainable urban drainage systems (SUDS), the implementation of sustainable drainage remains a very challenging task in reality. Many practical implementations of SUDS tend to underestimate their complexity, so the resulting performance is often unsatisfactory with respect to SUDS operation and maintenance, little to no co-ordination of interaction with other water bodies, and institutional impediments and barriers to SUDS practices.

Deep aquifers take time to replenish because water takes more time, perhaps weeks or even months, to move through unsaturated soil. If a surface water source is polluted, clean-up actions can be carried out without much difficulty, but remediation of a polluted aquifer is very difficult and expensive—or even impossible. FAO (2003) states that there is an inverse relationship between the vulnerability of aquifers to pollution and the difficulty of remediation. This is because fractured aquifers are more vulnerable to pollution and so permit rapid flow compared to the slow movement that occurs in porous media. Efficient and effective water management techniques are of paramount importance for groundwater sustainability (Patode et al. 2017). Adequate groundwater availability and sustainability can be ensured by proper public awareness and other appropriate measures (CGWB 2018).

1.9 Conclusion

Rainwater is the major source of recharge for surface and subsurface water. In semi-arid regions, groundwater and surface water sources have been exploited almost to the point of exhaustion. The main reasons for this are increased demand for water from various sectors and competition for water use in these sectors. Groundwater is a major source of water for drinking and irrigation purposes, but groundwater levels decrease daily due to climate change and high demand from industry and society. The overexploitation of groundwater sources has resulted in the lowering of water tables at alarming rates and the deterioration of water quality in aquifers. Surface water resources are also under threat because of their misuse. The quality of surface water resources is affected by industrial waste disposal and siltation due to heavy floods. Floods are common phenomena in Indian rivers. All these factors affect per-capita water availability in semi-arid regions. All governments promote water use efficiency in the irrigation sector. But there are many challenges in implementing micro-irrigation techniques to improve agricultural efficiency. To mitigate groundwater depletion and achieve sustainability, conjunctive use of surface and groundwater is an effective method where possible.

References

Abdullaev, I. (2004). The analysis of water management in Bukhara Oasis of Uzbekistan; historical and territorial trends. *International Water Resources Association, Water International, 29*(1), 20–26.

Al-Jawad, J. Y., Al-Jawad, B. S., & Kalin, R. M. (2019). Decision-making challenges of sustainable groundwater strategy under multi-event pressure in arid environments: The Diyala River Basin in Iraq. *Water, 11*, 2160. MDPI.

Biswas, S. K., Akanda, A. R., Rahman, M. S., & Hossain, M. A. (2015). Effect of drip irrigation and mulching on yield, water-use efficiency and economics of tomato. *Plant Soil and Environment, 61*(3), 97–102.

Centre for Science and Environment. (2020). *State of India's environment 2020 in figures. A down to Earth annual*, New Delhi.

CGWB West Central Region. (2018). *Ground water year book - 2016-17*. Faridabad: CGWB, Ministry of Water Resources, River Development and & Ganga Rejuvenation, GOI.

Cosgrove, W. J., & Loucks, D. P. (2015). Water management: Current and future challenges and research directions. *Water Resources Research, 51*, 4823–4839. https://doi.org/10.1002/2014WR016869.

Davis, A. A., Hunt, W. F., Traver, R. G., & Clar, M. (2009). Bioretention technology: Overview of current practice and future needs. *Journal of Environmental Engineering, 135*(3) March, 109–117.

Dehais, M. (2011). *Bioretention: Evaluating their effectiveness for improving water quality in New England urban environments*. Masters Theses 1911 in Master of Landscape Architecture submitted to Department Landscape Architecture and Regional Planning, University of Massachusetts Amherst.

FAO. (2003). *Ground water management: The search for practical approaches*. World Bank Reports.

GOI. (2005). *Dynamic ground water resources of India*. Jaipur: Central Ground Water Board, Ministry of Water Resources, Government of India.

Irrigation Association of India (IAI) & Federation of Indian Chambers of Commerce & Industry (FICCI) & Grant Thornton India LLP. (2016). *Accelerating growth of Indian agriculture: Micro-irrigation an efficient solution. Strategy paper – Future prospects of micro irrigation in India*.

Keller, A., Keller, J., & Seckler, D. (1996). *Integrated water resources systems: Theory and policy implications, Research report 3*. Colombo: International Irrigation Management Institute (IIMI).

Khadri, S. F. R., & Moharir, K. (2016). Characterization of aquifer parameter in basaltic hard rock region through pumping test methods: a case study of Man River basin in Akola and Buldhana Districts Maharashtra India. *Modeling Earth System and Environment, 33*, 2.

Khadri, S. F. R., & Pande, C. (2015). Remote sensing based hydro-geomorphological mapping of Mahesh River Basin, Akola, and Buldhana Districts, Maharashtra, india-effects for water resource evaluation and management. *International Journal of Geology, Earth and Environmental Sciences, 5*(2), 178–187.

Khadri, S. F. R., & Pande, C. (2016a). GIS-based analysis of groundwater variation in Mahesh River Basin, Akola and Buldhana Districts, Maharashtra, India. *IJPRET, 4*(9), 127–136.

Khadri, S. F. R., & Pande, C. (2016b). Ground water flow modeling for calibrating steady state using MODFLOW software: A case study of Mahesh River basin, India. *Modeling Earth Systems and Environment, 2*, 39. https://doi.org/10.1007/s40808-015-0049-7.

Khadri, S. F. R., Pande, C., & Moharir, K. (2013). Geomorphological investigation of WRV-1 watershed management in Wardha district of Maharashtra India; using remote sensing and geographic information system techniques. *International Journal of Pure and Applied Research in Engineering and Technology, 1*(10), 152–163.

Kumar, M. D. (2001). *Demand management in the face of growing water scarcity and competition in India: Future options*. Working paper 153. Gujarat, India: Institute of Rural Management Anand (IRMA).

Kumar, M. D., & Van Dam, J. C. (2013). Drivers of change in agricultural water productivity and its improvement at basin scale in developing economies. *Water International, 38*, 312–325.

Kumar, M. D., Sharma, T. H., B Amaasinghe, U., & Singh, O. P. (2008). Water saving and yield enhancing micro-irrigation technologies in India: When and where can they become best bet technologies? In M. D. Kumar (Ed.), *Managing water in the face of growing scarcity, inequity and declining returns: Exploring fresh approaches, Proceedings of the 7th Annual Partners Meet* (Vol. 1, pp. 1–36). Hyderabad: IWMI – Tata Water Policy Research Program, ICRISAT.

Kumar, M. D., Ratna Reddy, V., Narayanamoorthy, A., Bassy, N., & James, A. J. (2017). Rainfed areas: Poor definitions and flawed solutions. *International Journal of Water Resources Development, 34*, 278–291.

Meti, C. B. (2012). Studies on factors influencing the drip irrigation adoption, constraints and remedial measures to increase area under drip irrigation. *International Journal of Agricultural Engineering, 5*(2), 236–239.

Moharir, K., Pande, C., & Patil, S. (2017). Inverse modeling of Aquifer parameters in basaltic rock with the help of pumping test method using MODFLOW software. *Geoscience Frontiers, 8*, 1385–1395.

Moharir, K., Pande, C., Singh, S., Choudhari, P., Rawat, K., & Jeyakumar, L. (2019). Spatial interpolation approach-based appraisal of groundwater quality of arid regions. *Aqua Journal, 68* (6), 431–447.

Moharir, K. N., Pande, C. B., Singh, S. K., & Del Rio, R. A. (2020). Evaluation of analytical methods to study aquifer properties with pumping test in Deccan Basalt region of the Morna River Basin in Akola District of Maharashtra in India. In *Groundwater hydrology*. London, UK: Intec Open Publication. https://doi.org/10.5772/intechopen.84632.

Molden, D., Amarasinghe, U., & Hussain, I. (2001). *Water for rural development: Background Paper on water for rural development prepared for the World Bank*. Colombo, Sri Lanka: International Water Management Institute (IWMI).

National Water Policy. (2012). Ministry of Water Resources, Government of India, New Delhi.

Pande, C. B. (2020a). Introduction. In *Sustainable watershed development. Springer briefs in water science and technology*. Cham: Springer. https://doi.org/10.1007/978-3-030-47244-31.

Pande, C. B. (2020b). Watershed management and development. In *Sustainable watershed development. Springer briefs in water science and technology*. Cham: Springer. https://doi.org/10.1007/978-3-030-47244-3_2.

Pande, C. B. (2020c). Thematic mapping for watershed development. In *Sustainable watershed development. Springer briefs in water science and technology*. Cham: Springer. https://doi.org/10.1007/978-3-030-47244-3_3.

Pande, C. B. (2020d). Sustainable Watershed Development Planning. In *Sustainable watershed development. Springer briefs in water science and technology*. Cham: Springer. https://doi.org/10.1007/978-3-030-47244-3_4.

Pande, C. B., & Moharir, K. (2015). GIS-based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra India. *Applied Water Science, 7*(2), 2015.

Pande, C. B., & Moharir, K. (2018). Spatial analysis of groundwater quality mapping in hard rock area in the Akola and Buldhana districts of Maharashtra, India. *Applied Water Science, 8*(4), 1–17.

Pande, C. B., Khadri, S. F. R., Moharir, K. N., & Patode, R. S. (2017). Assessment of groundwater potential zonation of Mahesh River basin Akola and Buldhana districts, Maharashtra, India using remote sensing and GIS techniques. *Sustainable Water Resources Management*. https://doi.org/10.1007/s40899-017-0193-5. Published online 8 September-2017.

Pande, C. B., Moharir, K. N., & Pande, R. (2018a). Assessment of Morphometric and Hypsometric study for watershed development using spatial technology - A case study of Wardha river basin in the Maharashtra, India. *International Journal of River Basin Management*. https://doi.org/10.1080/15715124.2018.1505737.

Pande, C. B., Moharir, K. N., Khadri, S. F. R., & Patil, S. (2018b). Study of land use classification in the arid region using multispectral satellite images. *Applied Water Science, 8*(5), 1–11.

Pande, C. B., Moharir, K. N., Singh, S. K., & Dzwairo, B. (2019a). Groundwater evaluation for drinking purposes using statistical index: Study of Akola and Buldhana districts of Maharashtra, India. *Environment, Development and Sustainability (A Multidisciplinary Approach to the Theory and Practice of Sustainable Development)*. https://doi.org/10.1007/s10668-019-00531-0.

Pande, C. B., Moharir, K. N., Singh, S. K., & Varade, A. M. (2019b). An integrated approach to delineate the groundwater potential zones in Devdari watershed area of Akola district, Maharashtra, Central India. *Environment, Development, and Sustainability*. https://doi.org/10.1007/s10668-019-00409-1.

Patode, R. S., Nagdeve, M. B., & Pande, C. B. (2016). Groundwater Level Monitoring of Kajaleshwar-Warkhed Watershed, Tq. Barshitakli, Dist. Akola, India through GIS Approach. *Advances in Life Sciences, 5*(24), 11207–11210.

Patode, R. S., Pande, C. B., Nagdeve, M. B., Moharir, K. N., & Wankhade, R. M. (2017). Planning of conservation measures for watershed management and development by using geospatial technology-A case study of Patur Watershed in Akola District of Maharashtra. *Current World Environment, 12*(3), 2017.

Sahasranaman, M., & Arijit, G. (2018). *Waste water treatment for water security in India*. IRAP Occasional Paper No.13-0418.

Seckler, D., Amarasinghe, U., Molden, D., de Silva, R., & Barker, R. (1998). *World water demand and supply, 1990 to 2025: Scenarios and issues, Research report 19*. Colombo, SriLanka: International Water Management Institute (IWMI).

Tanji K. K., & Kielen N. C. (2002). *Agricultural drainage water management in arid and semi-arid areas*. FAO Irrigation and Drainage Paper 61.

Tiwari, K. N., Kumar, M., Santosh, D. T., Singh, V. K., Maji, M. K., et al. (2014). Influence of drip irrigation and plastic mulch on yield of sapota (Achraszapota) and soil nutrients. *Irrigation & Drainage Systems Engineering, 3*, 116. https://doi.org/10.4172/2168-9768.1000116.