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WHAT IS SMART WATERSHED MANAGEMENT?

SUMMARY

Smart management (SM) in different aspects of our planet earth is an emergence tool for today's world. Since the watershed is a basic unit for all agricultural, environmental, and socioeconomic researches and developments, so SM practicing at the watershed scale is critical. In this sense, SM in a watershed scale could be introduced as connectedness of the new Information and Communication Technologies (ICT) into watershed management practices to provide added value in the better decision making or more efficient exploitation operations and management. In this way, different ICT solutions such as precision equipment, the Internet of Things (IoT), sensors, geo-positioning systems, Big Data, unmanned aerial vehicles, and robotics need to be adapted by watershed stakeholders viz. the residents, farmers, experts, land planners, and managers, as well as the decision- and policy-makers. The smart watershed management (SWM) is associated with almost every luxury in our life and included all principles and concepts of smart water management, smart farming, smart city development, etc. It is essential to choose appropriate smart technologies that could be possible by comparing regular and novel technologies, balancing customary with green infrastructures, combining regional and universal knowledge, customizing options from abroad to regional situations, allocating with ecological and societal impressions of the substitute technologies. Altogether these decisions have need of technology appraisal and assessment tools and sound watershed governance to ensure pellucidity and

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comprehensiveness. It is challenging to ensure the proper utilization of watershed resources. However, proper implementation of smart technologies in the watershed will surely make our lives convenient and conserve our valuable resources. SWM can provide significant environmental and economic benefits.

Key words: Intelligence techniques; Market dynamic; Precise adjustments; SMART data.

INTRODUCTION

Watershed management is defined as the conserving, regulating, and managing the process of land, water, and other natural resources that are available in a watershed. Providing the proper goods and services without adverse effects on the ecological balance is the main target of the watershed management lately established by integrated watershed management [Wang *et al*., 2016]. Acknowledging the existing land use, soil, water, flora, fauna, and human communities in the watershed and their inter- and intra-relationships at the upland and downstream areas is the first step to achieve integrated watershed management [Ffolliott *et al*., 2002, Zardari *et al*., 2014]. Table 1 shows a list of targets that are more important and need to be taken into account while preparing a watershed restoration and conservation plan.

Table 1. Watershed management (WM) targets with their description and sources

WM targets	Source	WM targets	Source
Providing good water quality	[Haidary *et al*., 2013; Mirzaei & Jafari., 2019]	Protecting habitat for fish and aquatic species	[McConnaughey *et al.*, 2020]
Controlling soil erosion	[Fernández & Vega., 2016]	Protecting the natural/cultural heritage and forests	[Powell, 2000]
Flood controlling	[Brooks *et al.*, 2013; Tang *et al*., 2020]	Improving and managing the nutrient	[Lee *et al.*, 2019]
Protecting woodlands, wetlands and habitats	[Markle et al., 2018; Barbieri *et al*., 2019; Fang et al., 2020]	Improving the quality and quantity of groundwater	[Gupta *et al.*, 2019]
Balancing ecological, economic and social interests of watershed	[Zardari *et al.*, 2014]	Conserving rivers, lakes and streams	[Surasinghe *et al.*, 2020]
Promoting co - operation among countries	[Dieperink., 2000]	Upgrading and reconstructing ecosystem	[Loucks *et al.*, 2005]
Managing, evaluating and Increasing productivity	[Guangyu *et al.*, 2016]	Provisioning the ecotourism and entertainment	[Frijters & Leentvaar., 2003]
Strengthening vegetation	[Mosaffaie *et al*, 2019]	Monitoring the migration of birds	[Global Nature Fund, 2016]

With the complexity of all aspects of watersheds, including human activities, climatic, hydrology, social, and economic variables, the use of traditional watershed management tools and methods have become obsolete and needs to be upgraded. Today the smart management recognized as a new approach that uses very practical tools that applicable for different managerial subjects such as water management, ecosystem management, smart home forensics, irrigation, smart city initiatives, medical, etc. [Mulla & Mote, 2016; Shahanas & Sivakumar, 2016; Tadokoro et al., 2016; Do et al., 2018; Kamienski et al., 2019, Saiz-Rubio & Rovira-Más, 2020]. Towards this, we integrated this subject with watershed management and introduced an innovative framework, i.e., smart watershed management (SWM). Center for Watershed Protection [Center for Watershed Protection, 2006] integrated and aligned 14 municipal programs under Smart Watershed for the United States to manage urban watersheds, smartly. The used programs were:

"(1) Sub-watershed restoration planning,
(2) Stream and sub-watershed field assessment,
(3) Sub-watershed monitoring and reporting,
(4) Watershed restoration financing,
(5) Management of natural area remnants,
(6) Storm-water retrofitting,
(7) Urban stream repair/restoration,
(8) Illicit discharge detection and elimination,
(9) Maintenance, inspection, and enforcement,
(10) Smart site practices during the redevelopment,
(11) Watershed education and personal stewardship,
(12) Public involvement and neighbourhood consultation,
(13) Pollution prevention at storm-water hotspots
(14) Pollution prevention at municipal operations"

There are also some websites and organizations that are focused on smart approaches, especially. For example, "Smart Growth" that "covers a range of development and conservation strategies that help protect our health and natural environment and make our communities more attractive, economically more robust, and more socially diverse" (http://smartgrowth.org/). Different projects and tools were developed by Smart Growth under EPA support, as reported on the website. "EverBlue" is another example that works on the SWM. They believe that "conventional watershed management methods are expensive, inadequate, and challenging to implement. Towards this, "EverBlue" introduced SWM because of its cost-effective, easy-to-deploy filtration tools.

Information and Communication Technologies (ICTs) play a significant role in smart management. SWM can make the most of the social and economic well-being of composition ICT products and provides added values in better decision making or more efficient exploitation operations and management. In our idea, SWM is the use of integrated and real-time ICT. Different ICT solutions such as precision equipment, the Internet of Things (IoT), Hardware (Sensors and Sensors Adapters), geo-positioning systems, Big Data (mapping and information systems viz., GIS, RS, and GPS), unmanned aerial vehicles, and robotics operating systems need to be adapted by watershed stakeholders. Data collecting and integrating need to be adapted by means of “sensor networks or smart meter, data distribution using WiFi or internet, data processing, and storage using cloud technologies, modelling and analytics, and visualization and decision support using web-based tools” [64] at a watershed scale. Figure 1 shows an overview of the SWM schematic. In the following sections, we explained the potential tools that could help in the realization of SWM.

Figure 1**.** A schematic view of smart watershed management (SWM)

1. Internet of Things (IoT): Collecting Information

The term Internet of Things (IoT) was first thought by Kevin Ashton in 1999 in the framework of supply chain management [Ashton, 2009]. It is referred to as electrical apparatus of any dimension or competence linked to the internet for sharing information [Ansari *et al*., 2020]. IoT means broad communication between objects in order to create a smart environment. IoT is the future of the internet for the new generation, including a variety of technology [Shahanas & Sivakumar, 2016]. Every physical object on the IoT can interact without the aid of human intervention remains the same. The IoT is made up of a global network of objects connected to each other. Where each tool has a unique identification address, and these tools communicate based on standard communication rules and protocols [Gubbi et al., 2013]. A smart environment is also including the information and communication technologies that make the infrastructural and service components of an environment more knowledgeable, more interactive, and more efficient. IoT is a network of connected tools. The tools can be a sensor, cell phone, actuator, Radio Frequency Identification (RFID) systems, or anything that can transmit and receive information over a communication channel.

In order to activate comprehensive calculations on the IoTs, the basic three-tier construction needs to be discussed [Pande & Padwalkar, 2014]. "The first tier consists of a variety of 'things' or 'objects' such as sensors, mobile phones, actuators, etc. The middle tier is the network tier which can be wireless or wired for a reliable transfer of information generated/collected by the 'things' and technology uses protocols that exhibit high three-tier security" [Atzori *et al.*, 2010; Mutchek & Williams, 2014]. The abilities of IoT tools provide numerous advantageous applications to ordinary people, companies, industries, and governments (Figure 2) [Yaqoob *et al.*, 2019]. The IoT, alongside predictive analytics, supports the concept of SWM, practically. To this end, an example of an information-based SWM cycle is shown in Figure 3.

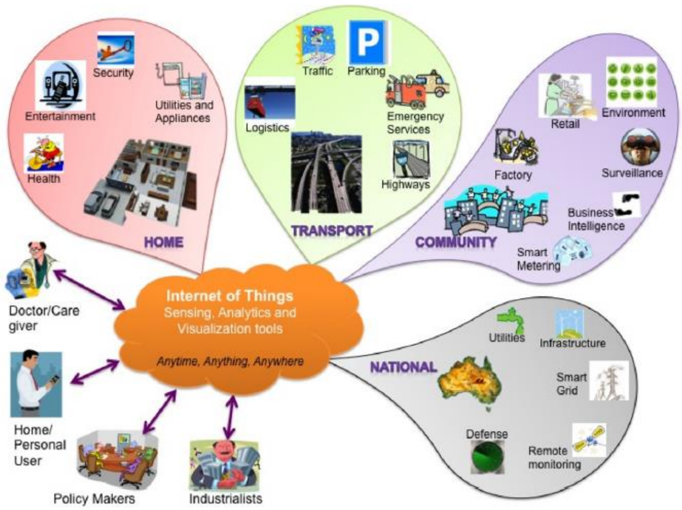

Figure 2**.** Potential Internet of Things (IoTs; [Gubbi *et al.*, 2013]) for smart watershed management (SWM)

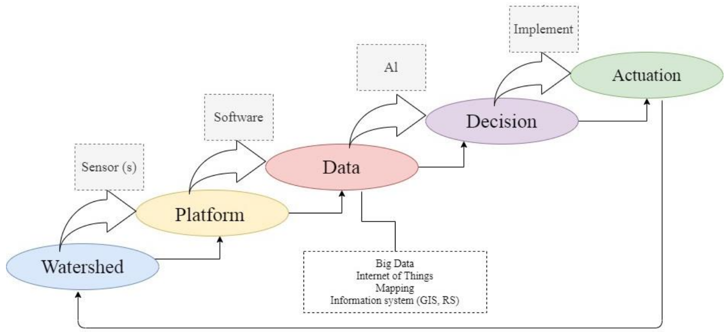

Figure 3. Information-based smart watershed management (SWM) cycle (Derived from [Saiz-Rubio & Rovira-Más., 2020])

2.Hardware: Sensoring Technologies

This layer of smart management could be named as the “eyes” of SWM. It used the elements of systems to record and transmits regarding watershed management data [Vlasov *et al*., 2018]. A sensor is a device that responds to physical, electrical, or magnetic input signals (with wired or wireless). It produces an output of measurement information in a form that is suitable for transmission, supplementary conversion, processing and/or storing, but which cannot be directly perceived by the observer [Freyden, 2005; Kozlova, 2009; Kabalci & Kabalci, 2019]. Extensively, systems that equipped with wired communication channels delivered a trustworthy transmission medium and an extraordinary speediness with long service life. A wireless sensor network involves a set of spatially-distributed intelligent sensors planned to monitor physical factors [Muyeen & Rahman, 2017; Vlasov *et al*., 2018]. Sensors placed in watershed units allow experts to obtain detailed maps of both topography and resources in the area, as well as dynamic monitoring of vital variables such as moisture, temperature, precipitation, etc.

3.Smart Data

Nowadays, information is essential for the prosperous supervision and operation of SWM. There is much information from the past, part of which is due to its public use of computers, communication networks, and sensors. In this age of Big Data, it has become likely to obtain, distribute, and process data close to real-time [Li *et al*., 2020]. According to the US National Institute of Standards and Technology (NIST), Big Data that is also useful for SWM consists of four dimensions of volume, velocity, and variety [Manyica *et al*., 2011; Sun & Scanlon, 2019]:

–Volume talks about Big Data size. The data volume is considered substantial if it is at a scale afar usual database software programs to collect, storage, accomplish, and process information, timely [Manyica *et al*., 2011; Saiz-Rubio & Rovira-Más, 2020]. In the past decade, using of Big Data was raised with the rapid development of ICT and IoT [Sun *et al*., 2019].

–Velocity discusses the facility to obtain, apprehend, and interpret events as they take place [Saiz-Rubio & Rovira-Más, 2020].

–Variety denotes the diverse formats of data used that could be as videos, text, voice, images, and the various complexity grades [Saiz-Rubio & Rovira-Más, 2020].

–Variability mentions the variations in entire other characteristics of the Big Data, such as, changes in data flow rates or dissimilarities in data meaning particularly in crowd-sourced data [Sun *et al*., 2019].

4.Mapping and information systems based data (GIS, RS, and GPS)

Maps visualize complex properties of our surroundings in a modest and clear manner for adapting different targets. The maps consider simplifications of reality, and it is not possible to represent the entire complications and minutiae. However, modern achievements of data acquisition, analysis, process, and visual depiction have enhanced that leading to better temporal and spatial resolutions of maps [DeLorme, 2001]. Map format has been recognized as the furthermost method to display watershed management data, because mapping is expedient to delineate spatial patterns and trends as well as homogeneous zones. Maps are also very useful to make efficient decisions; answer land management questions, provide and interpret the spatial information [Saiz-Rubio & Rovira-Más, 2020].

The geographic information systems (GIS) and remote sensing (RS) play an essential role in the SWM. GIS comprises a collection of hardware and software that captures geographic data efficiently, stores it for analysis and displays as per requirement [Martin *et al*., 2020]. GIS plays a significant role in the creation of SWM by utilizing geospatial data generated by various techniques. GIS-based planning of SWM can help in identifying alternative options and their potential impacts when required. The planning tasks could be also performed through functions of the GIS in terms of spatial analysis (Figure 4).

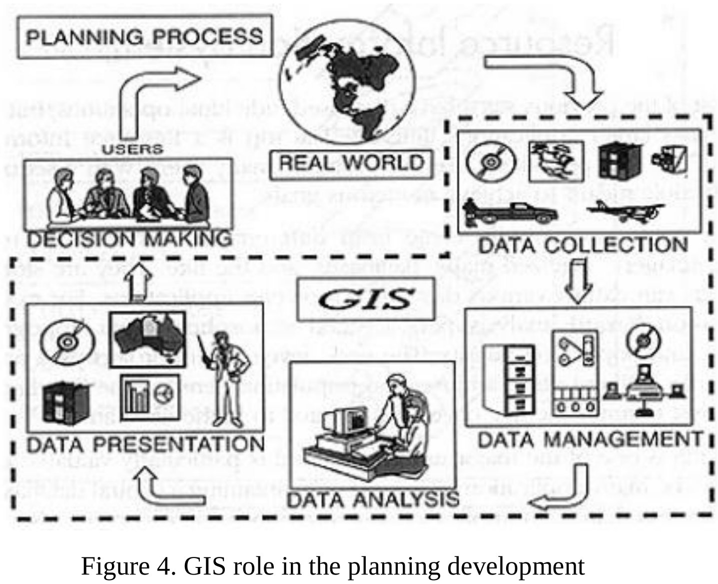

Figure 4. GIS role in the planning development
(http://rst.gsfc.nasa.gov/Front/tofc.html)

The RS technique implicates information mining in respect to diverse object of the earth, indirectly. Geo-spatial data collecting from remote devices (such as sensors) has been used for analysis. Traditionally, acquiring data typically by optical and radar sensors based on the satellite and airborne platforms was referred to RS [Schowengerdt, 2006]. Whilst, currently, any acquisition means of image and spatial figures (such as airborne surveying and photogrammetry) has been considered as RS [Mikhail et al., 2001], though the satellite-based RS and mobile mapping for terrestrial platforms, are still sporadically applied [Toth & Jóźków, 2016]. RS is useful in numerous SWM targets, for instance sensing moistness, evaporation, and transpiration of soil, condition evaluation (land cover, snow cover), trend changes (temperature, precipitation, etc.) classification of land use, watershed health, and compliance of agriculture monitoring.

The RS process encompasses the relations concerning incident radiation and the targets of interest. Figure 5 shows the imaging systems where the following seven elements (visible light, radio-waves, micro-waves, infrared, UV rays, x-rays, and gamma rays) are involved. Note, however, that RS also involves the sensing of an emitted energy and the use of non-imaging sensors (Figure 6). RS can be broadly classified into three types concerning the wavelength region and type of sensor involved for data acquisition; viz. optical (Visible and Reflective Infrared), thermal infrared and microwave [Gao *et al*., 1998; Murino *et al*., 2014; Lei *et al*., 2020].

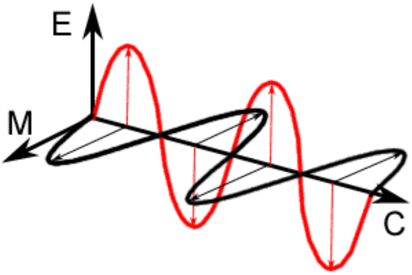

Figure 5. Electric wave (E) and magnetic wave (M) materializing the electromagnetic wave
(Source: http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php)

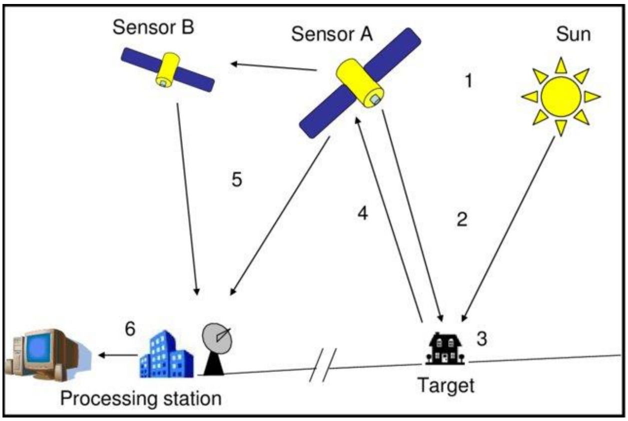

Figure 6. RS process stages
(http://www.ansp.org/museum/kye/tech_environment/2001_remote_sensing.php)

One way to determine the geo-positioning is Global Positioning System (GPS). GPS is a satellite-based navigation system applied to locate a geo position anywhere on earth, using its longitude and latitude. It fixes the precise geodetic location and elevation on the earth's surface. The marvellous applications were known for GIS data collection, monitoring, and plotting using GPS technology [Hanna *et al*., 2012]. Figure 7 shows a view of satellites orbiting the earth.

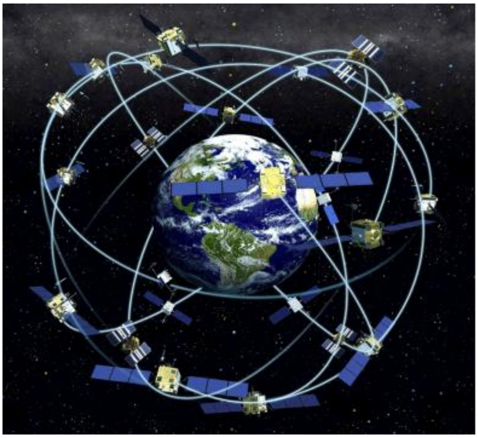

Figure 7. Arrangement of NAVSTAR satellites circling earth
(Source: www.linuxjournal.com)

5.Unmanned aerial vehicles systems

Using of an unmanned aerial system (UAS) as a communication platform and an innovative technology has a marvellous prospective in watershed management [Boursianis *et al*., 2020]. UAS is an aircraft without a human pilot on board, which can experts autonomously or controlled telemetrically to carry out a special mission [Boukoberine *et al*., 2019]. Low cost and high mobility are two benefits of UAVs when capturing aerial snapshots [Liu *et al*., 2014]. UAS can provide flexible, fast, and cost-effective tools for inspecting watershed management [Mota *et al*., 2014]. Figure 8 shows a prototype UAS platform.

Figure 8. A prototype UAS platform [Guerra *et al*., 2020]

6.Robotics Operating System

Studies on sensory feedback control for robotic operating systems (ROCs) in subject of smart management have recently risen [Fitzpatrick *et al*., 2008; Wang *et al*., 2016]. The ROCs can interact, assimilate motion, and handle functions to promote or substitute human beings in diurnal responsibilities [Boursianis *et al*., 2020]. To produce these kind of ROCs, there are several engineering methods [Niazi & Hussain, 2011] and support technologies [Iñigo-Blasco *et al*., 2012] available, with the multi-agent system (MAS) being one of the most successful [Guerra *et al*., 2020].

7.The necessity of smart management adaptation

Smart management provides many applications for easy human access to a better life, which can be referred to as some of these:

Smart City: The literature showed that the percentage of the city inhabitants will continue to rise. Therefore, the urban development and planning could be promoted through a smart digital city [Batty, 2007]. For example, the use of smart management in India has been very efficient. Smart parking, intelligent traffic management, and integrated multi-faceted transportation have brought smart transportation to the city. Further values could be added to the smart environments using adaptation of smart waste management, air quality monitoring, and noise monitoring systems [Shahanas & Sivakumar, 2016].

Smart Climate: Climate is the major uncontrollable factor that influences crop yield and has been accepted as one of the factors contributing to yield stagnation globally [You, 2009; Gichenje & Godinho, 2019]. Improvements in crop yields have slowed since the 1990s [Rosegrant & Cline, 2003] and even stagnated in much of the world since the last century [Ray, 2012]. Climate-smart soil management incorporates total sustainable management practices and associated environmental, cultural, social, and economic activities within the framework of a changing climate [Garcia-Franco *et al.,* 2018].

Smart Water Management: Water is vital components of our earth to our life style, and universal water-related concerns consist of short supply and uneven distribution. To this end, smart water analytics provide a change by dint of bringing real-time data in front. Therefore, the analysts will spend short time and do quick actions on the data analysis at a low cost [Shahanas & Sivakumar, 2016; Nguyen *et al*., 2018]. According to many studies [Choi & Lee, 2013; Byeon *et al.*, 2015; Choi *et al.*, 2016], it can be stated that using a smart system can be managed. Smart water management can be a useful and effective method to improve water quality and quantity.

Smart Farming towards Agriculture: Growing population and rushed climate changeability worldwide has placed immense pressure on agricultural foodstuffs [Virk *et al*., 2020]. According to the result, smart management can provide helpful knowledge for farmers to elevate their living ideals, through high yield, and income and also can be a sound food security index [Rodríguez *et al*., 2019, Kumari & Iqbal, 2020].

CONCLUSION

Being smart is a vital step for our earth management. As the researchers conclude that everything on this planet is created smartly, so smart tools are needed to use, save, and manage the earth's planet resources and even developing new ones. Smart Watershed management (SWM) is one of the interdisciplinary subjects that need to establish, globally. Because the watershed is known as a basic unit for land planning, then achieving smart management is essential at a watershed scale. In this regard, linking the recent human achievements in the field of Information and Communication Technologies (ICT) with watershed management strategies is very useful. According to the literature review, various programs are suggested, but undoubtedly there are strengths and weaknesses for each program. Therefore, selecting the best one based on the governing situation of the watershed and mixing some of them, also need smart thinking. SWM is direct links smart tools to watershed restoration practices and creates a robust practical basis to advance a comprehensive and action-oriented rehabilitation plans. SWM, with the help of digital technology, improves the data collection methods and analytics to support proactive decisions and increase the efficiency of watershed utilities.

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