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Spatial Solutions Based Geo-information Methods for Sustainable Integrated Water Resources Management

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Abstract: This paper presents spatial solutions based on advanced geo-information technologies for integrated water resources management. This will ensure the coordinated development and management of water resources to optimize economic and social welfare without compromising the sustainability of environmental systems. Also section 2 presents the current water situation in Syria, while Section 3 outline the need of the water demand management in Syria. Section 4 describes the use of geo-information technologies for providing spatial solution for integrated water resources management. A case study on the Syrian cost region will be presented and then this will be generalised on all Syrian regions. The paper ends with some conclusion and future work.

Key words: Water • GIS(Geographic Information Systems) • Geo Information technology • Surface Water System • Drink Water • Irrigation • RS (Remote sensing) • water management • GNSS (Global Navigation Satellite Systems)

INTRODUCTION

Water resources, that are distributed in time and space, are at the heart of sustainable development in many regions of the world. The social, economic and industrial development, rapid population growth, diffuse pollution from agriculture and various alterations in land use or hydro-infrastructure may all has increased the demand for water supplies in arid and semi-arid areas (e.g., Syria) both as consumptive and non-consumptive uses and consequently contributed to non-sustainable use of water resources. Other problems are the aridity (low rainfall and high evaporation), deterioration in water quality, complexity in hydro-politics (water sharing/conflict), etc. Hence, the complexity in the problems of water management is increasing and the environmental degradation is continuing and this require a clear methodology to understand the operational needs that handle inter-related risk and environmental impact of these problems (Choukr-Allah, 2009). Therefore, this paper presents an advanced spatial solutions for integrated water resources management which is needed to ensure the coordinated development and management of water, land and related resources to optimize economic and social welfare without compromising the sustainability of environmental systems. These solutions will be coupled with geo-information technologies to provide easy access to relevant data and support the integration of the approaches of water management that ensure sustainability of the resource. This will enable decision makers and water utilities to consider these solutions, where appropriate, as part of the water supply portfolio, taking account of costs, security, quality of supply and environmental and social benefits.

The Current Water Situation in Syria: The water sector of Syria (185,000 Km2 with population of 20 Million) is of high strategic importance for the development. High population growth, continuing urbanization and associated economic growth have already increased the pressure on water resources which have resulted in an acceleration of the degradation process. According to the Syrian Central Bureau of Statistics (Statistical Abstract 2006, table 8/5), that the average population projection for the year 2010 (20.5 millions) and the anticipated urban/rural composition of population in the year 2010 (54.5% urban/45.5% rural). This is calculated from 2007 composition (53.5% urban/46.5% rural) and the current

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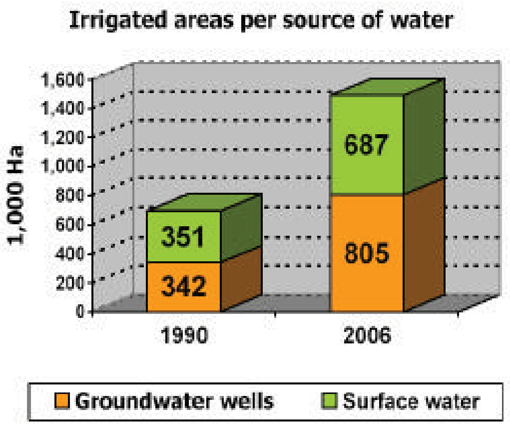

Fig. 1: The irrigated areas per source of water (NBPR,2007)

Table 7: The Internal Groundwater Availability per capita in Syria

Country	Internal Groundwater availability per capita (Measured per thousand cubic meters)
Maximum	110.27
Minimum	0.00
Syria	0.23

Source: (Source: Plan Blue, Water Use Efficiency in Syria, National Report, Al-Azmeh, 2008)

average urbanization rate (0.33% per annum, or 1% every 3 years). Proposed by the expert on basis of the following data/assumptions: the average population projection for the year 2015 (23.0 millions) which is the one-decimal rounded average of the high and low projections (reported in the 1st National Population Report, 2008) coverage with drinking water supply in the year 2015 to reach 91.8% of whole (Al-Azmeh, 2008).

Syria depends on surface and ground water (springs and wells) for agricultural sector and domestic supply as shown in Table 5. Agriculture is the largest consumer of water (about 85%) and the economy of the country depends directly on it (30%GDP) and up to 40% (directly and indirectly) to employment. Figure 1 illustrates the comparison in the expansion (in total 215%) that happened during the period 1990-2006 in the irrigated areas (196%) from surface water sources (including rivers, springs and public irrigation projects) and irrigated areas (235%) from groundwater. It can clearly be seen that the greater expansion is due to the groundwater wells compared to surface sources and the consequents of this is that the yearly extraction from groundwater reservoirs has exceeded by far the groundwater renewal rate in the whole country. According to the (NBPR, 2007), the current extraction has exceeded 8.5 km^3/year against an average of 2.7 km^3/year considered extractible without permanent negative effects on natural springs' flows. Hence, the main challenge for the whole water demand management in Syria is to improve water use efficiency.

Water management in Syria has focused in the last 4 decades on water supply, (160) dams were built, large irrigation projects to supply cities and villages with water to encourage agricultural and industrial expansion. Competition among agriculture, industry and cities for limited water supplies is already constraining development efforts in many parts of the country like Damascus, Aleppo, Homs and Hama and this will intensify, causing difficulties in specific regions. Those problems are clearly observed in greater cities where rapid urbanisation has been accompanied by an increase in population. This significant growth of population will create complicated issues related to water demand in the future. In addition, the country faces a number of challenges related to water: aridity (low rainfall and high evaporation), deterioration in water quality, degradation of quantity of surface water and decreasing groundwater levels, social and economic development, complexity in hydro-politics (water sharing/conflict) (almost 70% of total resources), efficiency in water distribution and use, public awareness and education, water strategies/institution/human resources, limited wastewater treatment capabilities, restricted private sector involvement and land use. To efficiently face these problems, the improvement of integrated water and urban development system in Syria will be required to address water quantity and scarcity issues for the next 25 years. The objective of this paper is to present and investigate potential spatial solutions for sustainable water resources management by incorporating geo-information technologies into water and new or existing urban development plans in Syria. Also, to calculate the water needed to meet the predicted demand in 2025 and offer some insight for the decision makers in Syria to consider when formulating guidelines about the development of water conservation programs in the future.

With regards to the groundwater which is an important source of drinking water in many countries and the most reliable and safe source of drinking water in arid and semi-arid zones and small islands. Nearly half of the world's population depends on groundwater for its drinking water supplies. The more groundwater is available per capita, the higher the probability that a country can sustainably manage its groundwater resources (e.g., for agricultural production). The excessive groundwater extraction due to rapid increase of water demand has resulted in a sharp decline of

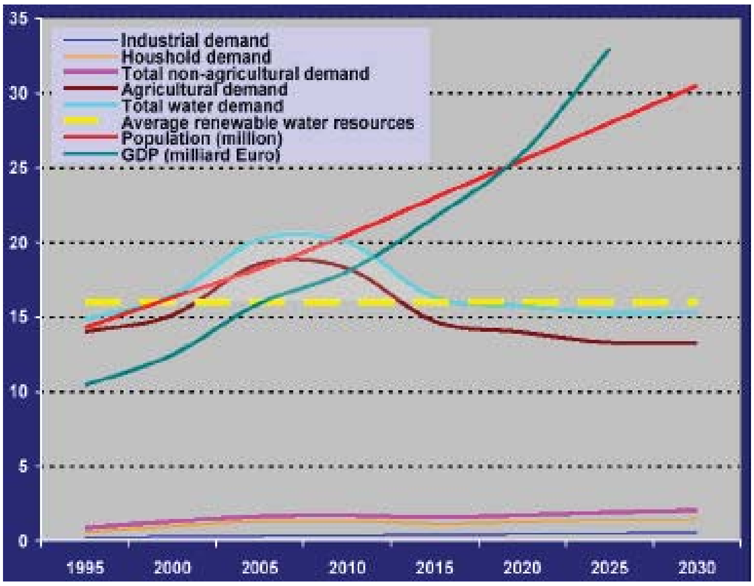

Fig. 2: Water demand against average renewable water resources (km3/year), compared to population and economic growth in Syria (Al-Azmeh, 2008)

the groundwater level. Better understanding of groundwater systems and dynamics based on groundwater investigation, monitoring and assessment (both renewable and non–renewable) has led to increasing use of groundwater for drinking purposes in many parts of the world. Table 6 gives the values of internal groundwater availability per capita for Syria.

The Need of the Water Demand Management in Syria: Considering the water situation presented in the previous section, the new water strategy of the Syria has clearly prioritized the use of water resources as follows: potable (household) water, industry (including tourism) and modern irrigated agriculture. As shown from the Figure 2, that there was a kind of parallelism (during the period 1995-2005) between the growth of population and the growth of the total water demand and this was due to the agricultural demand (and not due to the growth of potable and industrial water demands) to cover the requirements of the food security (Al-Azmeh, 2008). This figure illustrates that the agricultural water demand has dramatically increased over the last ten years and this is due to the expansion in irrigated areas that sourcing water from dams and wells. On the other hand, the non-agricultural water demand (industrial and household) steadily increase with population and economic growth. Water usage has exceeded in value the national renewable water resources due to the dramatic increase in agricultural water demand during the period 1995-2000 and this shortage was being compensated from extracting non-renewable groundwater. This was caused lower-flow or even dry-out of many natural springs and significant reduction of groundwater levels in many hydrological basins in Syria. However, implementing modern irrigation techniques, the current shortage gap between the national water uses and resources is expected to shrink down during the period 2009-2011. Also, it appears from the future trends in this figure that Syria has a good opportunity to separate the growth of total water demand from the growth of population and GDP. The actual results of the researches and experiences in this domain have proved enough that the conversion to sprinkler, localized and modified surface irrigation modes is accompanied for all major national crops (and not only by high water savings but also higher land use).

In conclusion, the sustainability of economic growth and social development in Syria became increasingly dependent on a meaningful water saving through raising water uses efficiency and strict application of the integrated water resources management, otherwise there will be critical water crises in the near future. Geo-information technologies provide practical solution for important issues facing water supply practices. The coming section aims to provide information about the use of geo-information technologies for providing spatial solutions for integrated water resources management in semi-arid and arid areas such as in Syria. A case study on the Syrian coast and then to be generalised on all

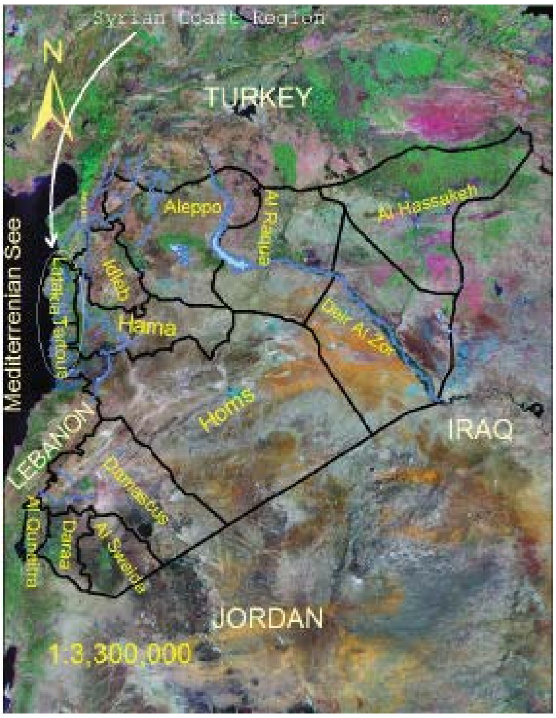

Fig. 3: The general map of Syria with surface water situation the background is satellite photo from Land-sat with 15 m resolution

Fig. 4: The surface water system in Syrian coast "Tartous and Latakia". (main rivers and lakes are surrounded by red circle for clarity)

Syrian provinces as shown in Figure 3. The surface water system (including main rivers and Lakes) in Syrian coast "Tartous and Latakia" is depicted in Figure 4 in which the lakes are surrounded by red circle for clarity.

Geo-information Technologies for Spatial Solutions: More than 85% of all the information used by water management is geographically referenced. The developed system utilizes the strengths of the geo-information technologies (Geographic Information Systems GISs, Remote Sensing RS, Global Navigation Satellite Systems GNSS, Internet, etc) in providing and representing spatial data and dynamic models in analyzing and representing temporal processes. Satellite imagery, which is in digital format, allows for the acquisition of environmental data and land occupation patterns and features over large areas. The main limitations of satellite images are cloud cover and resolution. Some of these problems may be circumvented using GNSS receivers. When associated with GIS, a GNSS receiver is the main reliable source for quick and accurate on-line information as well as a powerful dynamic mapping tool. Vegetation, land-use patterns, surface waters, quality and humidity of the soil, tracking the environmental characteristics and changes useful to the study of resources of freshwater and climatic changes may all be monitored by GNSS satellites. GISs facilitate the integration of quantitative water determination and control data with data obtained from maps, aerial photos, satellite images and satellite navigation systems (Saleh and Dare, 2002a, 2002b).

Case Study on the Syrian Cost Region: The water supply variability in Syrian regions implies several important constraints in water management. One of these constraints, expensive storage capacity is required to utilize the variability of flows in space and time, subjecting the stored water to evaporation losses (e.g., 14% of the Nile flow is lost due to the evaporation). Effects of mixing of recovered water with other sources of drinking water quality and integrating infrastructure also warrant evaluation at demonstration sites (Saleh and Allaert, 2008). Such research at the interface between integrated water management and urban planning would benefit from demonstration projects. The objective here is to ensure the long term conservation of the water resources in Syria in general and in the coast area in

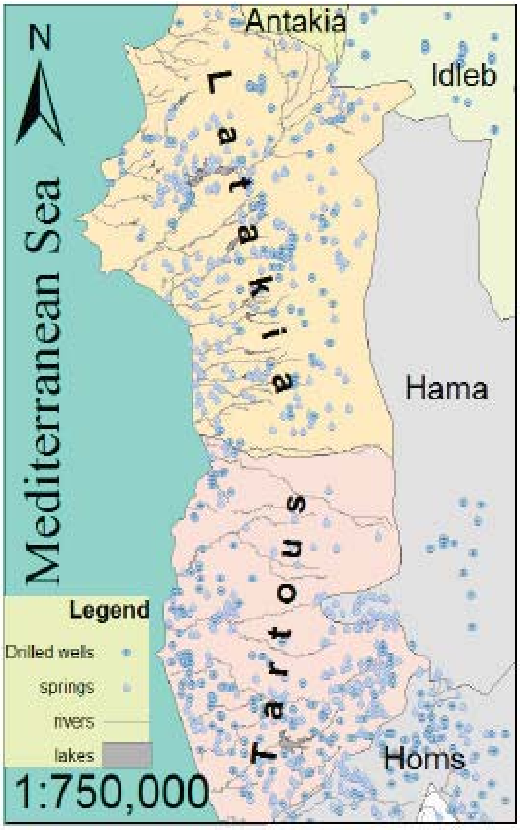

Fig. 5: The Ground water system in Syrian coast "Tartous and Latakia". (Main spring and drilled wells used mainly for drink water, river and lakes are in gray for reference)

particular through building facilities and setting up a water resources network to foster the cooperation between the partners with respect to training, research and public awareness.

We can here demonstrate the power of using Geo information systems by a simple project such determination the sensitive areas in the coastal region in water resources maters.

First the determination of the criteria of sensitive area, then determination the data needed.

Before the criteria we need to determinate risks and its sources.

The risks of polluting water resources, ground water or surface water:

- Urban area with a bad waste water management
- Roads (in case of camion accident transporting a chemical product)
- Factories, gas-stations, Oil refinery.
- Pollution comes from fertilizers and pesticides that Agricultural uses
- Municipal solid waste

The Criteria: These sources of pollution must not affect the water resources; this will be managed by applying certain criteria when choosing the place of polluted facility.

- Near ground or surface water resources
- In low sloped land permeable
- In sloped land near rivers
- Far from earth cracks

Each of these criteria need a research to determinate the particularity of using it, this will not be discussed in this paper, but we will put this particularity as logical as possible, for example the polluted facility must be:

- far from upper side of spring more than 300m
- not in permeable land or over ground water with 30 m depth
- not near lack or river less than 300 m depending on the terrain slope.
- Earth cracks let the pollution go directly to the deep ground water so we have to protect the ground water we have to make a minimum distance between the pollutant and the earth crack let us suppose 200 m

The Data We Need:

- Surface water system, rivers, lacks, drainage system
- Ground water system, springs, wells.
- Land use
- Digital terrain model

Land use helps to determinate the pollution uses of land like agricultural areas, industrial areas, high populated area (Figure 6).

The Digital terrain model gives the altitude of each point (Figure 7), from which we can extract the slope.

The drainage system is very important as sensitive area as it can take the polluted water to lakes and rivers (Figure 7).

The way of working consists of making a buffer of determinate distance from each sort of water resource (Figure 8).

Adding these entire buffers together (figure 9) gives the desired sensitive map.

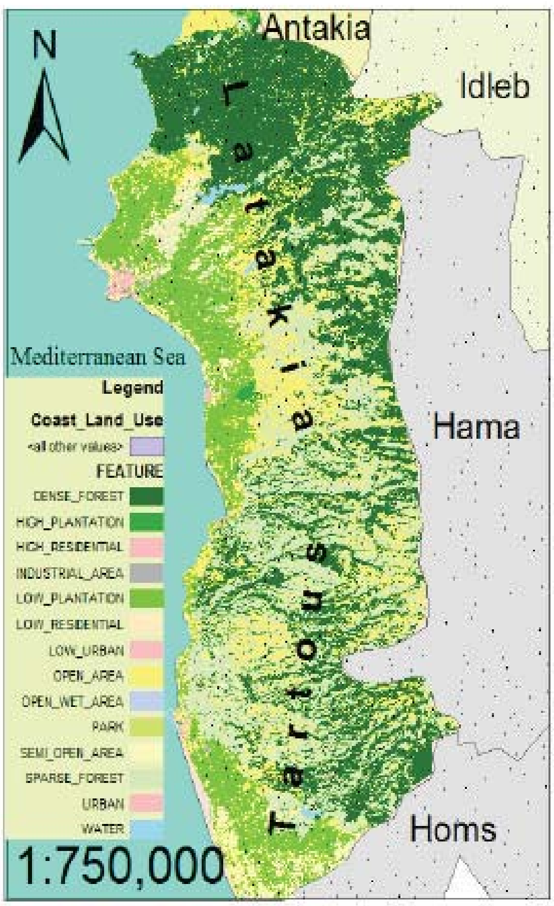

Fig. 6: Shows the land use of the coastal area of Syria

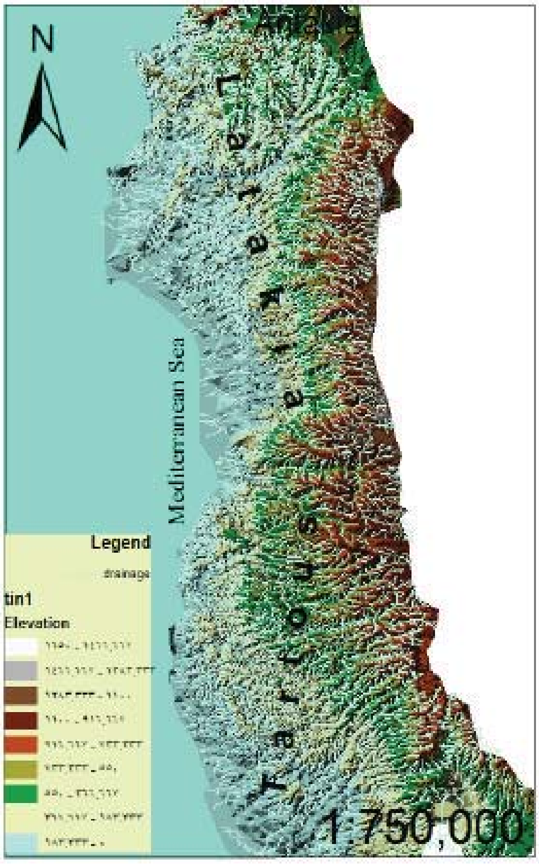

Fig. 7: Shows the drainage system and the Digital Terrain Model of the coastal area of Syria

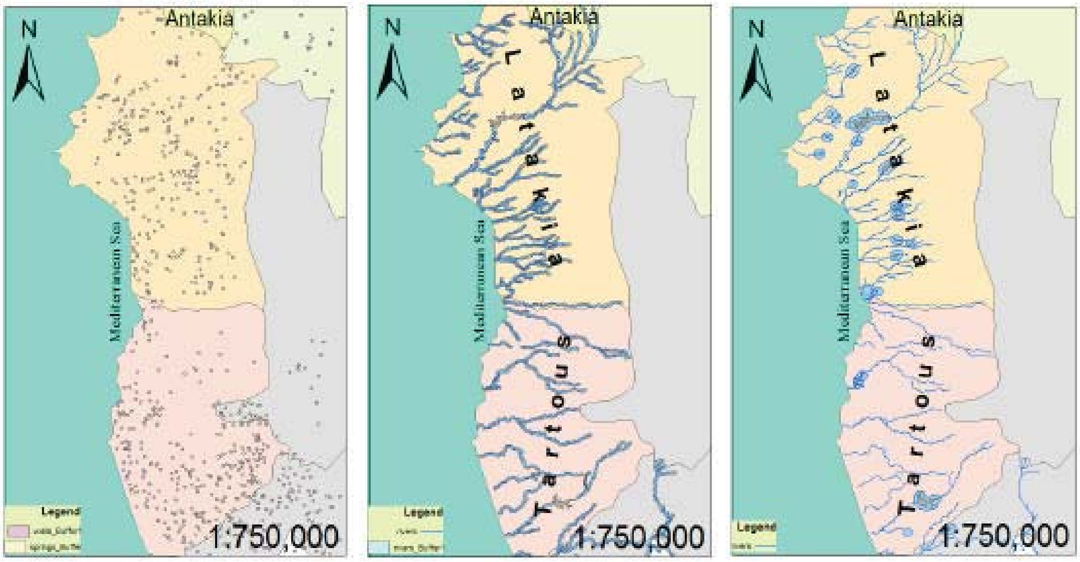

Fig. 8: Shows buffer around: wells and springs, rivers, lacks

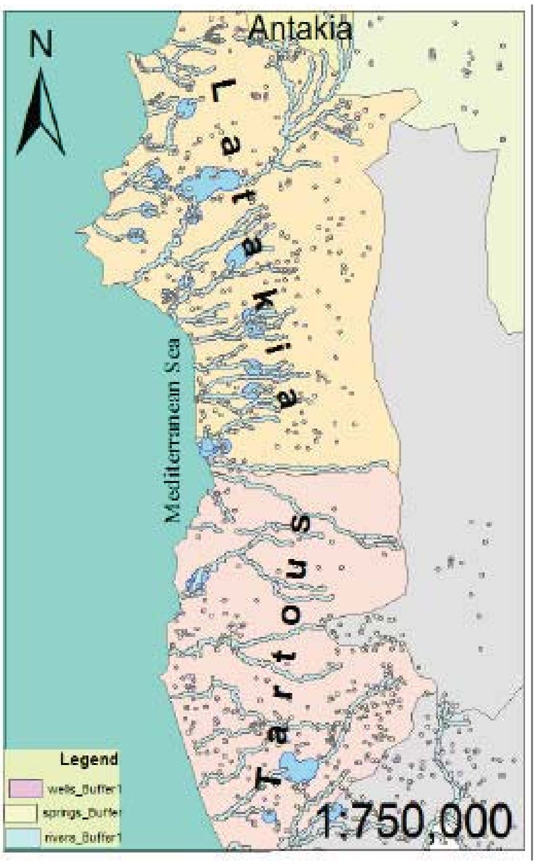

Fig. 9: Shows addition of all buffer together in a visual way

The sensitive map comes from the spatial analyses of the coastal region taking in consideration all criteria discussed before.

Adding all these map to gather gives us the sensitive map:

This example can be expands to take in consideration the slope, the ground water depth, the use purpose of each lack and spring and drilled well.

The spatial analyst tool in GIS can go even farther in effectiveness in giving us a whole raster map of determinate where to construct certain sort of polluted facility without harming the water system resources.

The sensitive map gives a valuable tool shows to decision makers where to build polluted facilities.

CONCLUSION

This paper constitutes an important step in water management by elucidating how geo-information technology could be efficiently introduced in the design process of water management to potentially provide optimal solutions than existing methods. A case study on the Syrian coast was presented with all the availability of water resources

Therefore, the main purpose of this research is to develop new methodology for effectively optimising the use of this technology coupled with long-term sustainable environmental planning strategy for water management.

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