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Review

Irrigation system in Israel: A review

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The objective of this paper was to review the irrigation system of Israel and to identify the most common irrigation methods used for safe, efficient and sustainable agricultural production in arid and semi-arid regions of the world. Israel is one of the most densely populated countries in the world and characterized by desert and semi-desert climatic conditions. Major constraints of the country include: Frequent droughts, desertification of agricultural land, rapid urbanization, depleting resources: technological uncertainty and high cost of non-conventional sources, degradation of water quality and increased water scarcity. Among these constrains, water scarcity is the primary limiting factor in Israel agriculture while the country depends on irrigation. The main water source for agriculture is pressure drip irrigation systems. Drip irrigation has the highest water efficiency rate in agriculture, reaching a 70 to 80% rate, versus open irrigation, which achieves 40%. Recycled use of water, waste water, adding nutrients mixed in with the water and desalination are the recent new innovation used to solve problem of water scarcity in Israel. Therefore, technology currently innovated to alleviate problem of irrigation water resources by Israel should have to be adopted in arid and semi arid of the world to increase the productivity.

Key words: Water resource, types of irrigation, drip irrigation system in Israel.

INTRODUCTION

Israel is one of the most densely populated countries in the world, while yet only 20% of the land is arable and half of that has to be irrigated. More than half of Israel is arid or semi-arid, and the rest of the country is dominated by steep hillsides and forests (http://www.jewishvirtuallibrary.org/). Israel on a land area of 20,770 km^2 is divisible into three longitudinal strips running from north to south. The average annual rainfall varies from 600 to 700 mm in the north to 30 mm at the south. Israel's population is 6.0 million, of which 90% lives in urban areas and 10% in rural areas. The number of farming households is 25,000. Farm employment contributes 3.1%, of the total employment, equivalent to approximately 67,000 persons. Out of the total area, arable land amounts to 652,000 ha. The area actually irrigated is 230,000 ha or approximately 35% of the arable land. The land holding allotted to a farming unit in the collective and cooperative settlements vary in size,

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according to the soil and climatic conditions. The average holding is 7 ha (www.un.org/esa/agenda21/natlinfo/).

The State of Israel is characterized by desert and semi-desert climatic conditions. Israel relies on approximately 4 sporadically rainy months for the annual replenishment of all of the nation's natural water sources. This water is largely contained within three main aquifers, and the Sea of Galilee watershed (Rejwan, 2011). In Israel, where climatic conditions change from semi-arid in the north to arid in the south, agriculture is completely depended on irrigation. The amount of water utilized annually exceeds 90% of Israel's entire water potential (Elke, 1998).

Israel's agriculture is characterized by high technological level, pressure irrigation systems, automatic and controlled mechanization and high quality seeds and plants. Israel meets most of its food requirements through domestic production to produce over 5 million tons of field crops, 1.15 billion liters of milk, 1.6 billion eggs and 1.2 billion flowers for export (www.un.org/esa/agenda21/natlinfo/). While the major constraints include: increased water scarcity; depleting resources, frequent droughts; degradation of water quality; technological uncertainty and high cost of non-conventional sources; rapid urbanization, abandonment and desertification of agricultural land (www.un.org/esa/agenda21/natlinfo/). Water scarcity is the main limiting factor in Israeli agriculture and the country depends on irrigation to increase its crop yields; about 50% of the land is irrigated. Of the 1,129 million cubic meters (MCM) of water used by agriculture per year, some 30% of agricultural water is treated wastewater (TWW) for drip irrigation of orchards and non-food crops, while another 16% is saline water.

Israel achievements in water resources development, agricultural production and irrigation technology are marked by the magnitude of the still facing problems of quantity, quality and cost of water for irrigation. Experience in water management is often considered unique, reflecting technological innovation, national commitment and ambitious development objectives. While there have been several mistakes along the way, the results of Israeli policies speak for themselves. During a sixty year history, the country's population has grown seven fold: from one to seven million residents. Orenstein (2004), Natural water resources have not increased but agricultural productivity has steadily increased and now is 1600% higher than it was in 1950! Automation of irrigation is one of the means to raise crop production per unit of water, through a strategy that aggressively utilizes waste water, drip irrigation and more recently desalinized sea water. Israelis enjoy a high quality of life which belies the remarkably low 300 m^3 per capita level of water (Tal, 2006). Therefore, the objective of this paper is to review the irrigation system of Israel and to identify the irrigation system that could be effective in arid and semi-arid region for efficient utilization of scares water resources in Israel.

LITERATURE REVIEW

Changes in agriculture over the last century have led to substantial increases in food security through higher and more stable food production. However, the way that water has been managed in agriculture has caused wide scale changes in land cover with watercourses, contributed to ecosystem degradation, and undermined the processes that support ecosystems and the provision of a wide range of ecosystem services essential for human well-being (Malin et al., 2007).

Global distribution of water resources

Among other natural resources, water resources have a unique position. Water is the main extensively distributed substance across the world. It contributes to a key role in the human life and surrounding environment. Fresh water is the most important among them, which is essential for human beings' life and activity. About 1.4 billion km^3 water is available on earth. Among them, approximately 35 million km^3 freshwater resources are present (nearly 2.5% of total volume), the distribution is shown in Figure 1 (UNEP, 2001).

On one hand, water resources are tends to depleting due to exceeding demand and consumption ratio. As a result of over pumping and demanding human activity, water quality is worsening in the sources. By considering worldwide population of 8 billion and with a raise of 2 billion dollars and as a common situation of business-as-usual, with enhance in water exploring of 22% over 1995 levels is predicted by 2025. It means irrigation demand raise up to 17%, including 20% demand for industrial water and 70% demand for municipalities' water (Rosegrant et al., 2002). On the other hand, Global warming further spells out such water shortage. Due to global warming, snow and ice in the Himalayas, which give huge quantity of water for agriculture in Asia, is estimated to reduce 20% by the year 2030 (UNDP, 2006). At present Irrigated agriculture contributes 40% worldwide food production. Irrigation increases crops yields from 100 to 400% but poor drainage and irrigation practices have led to water logging and salinization of about 10% of irrigated land over the world (http://www.actionaid.org/docs/gold_rush.pdf).

Major irrigation systems in the world

Irrigation systems are divided into 2 categories: gravity-fed systems and pressurized systems:

Gravity systems

(i) Irrigation pond: Water is provided in the form of a

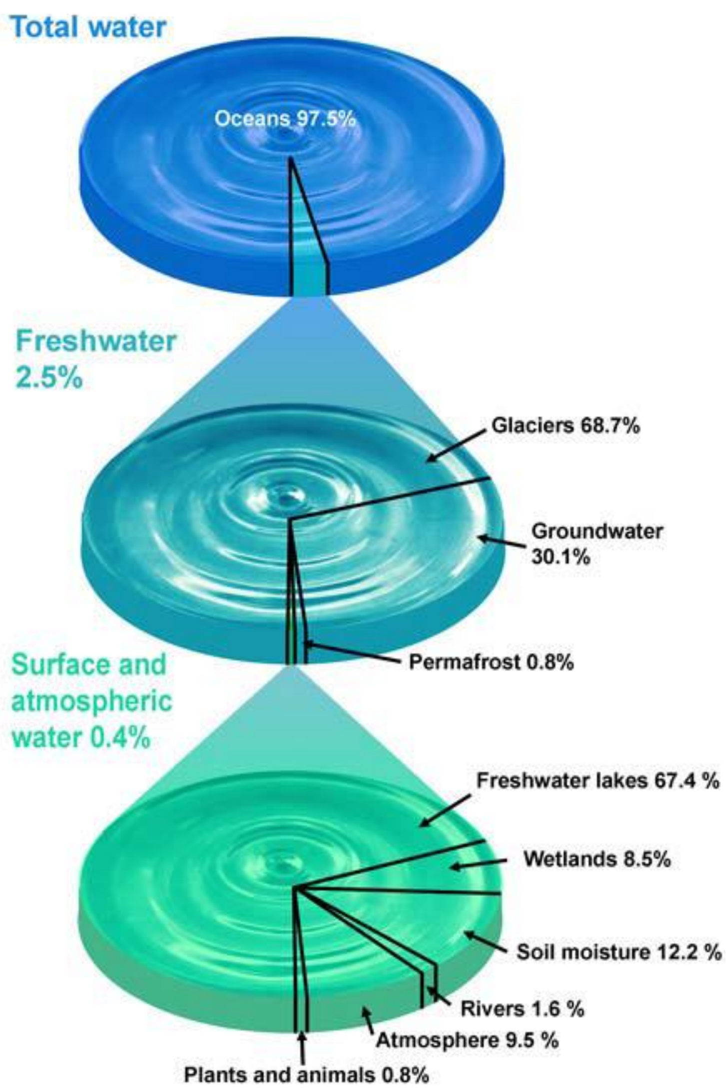

Figure 1. Global distribution of water resource. Source: UNESCO, the United Nations World Water Development Report 2, UNDP, 2006.

tablecloth in a basin (which can be partitioned) built on a leveled ground (slope of 0.1 to 1%);
(ii) Irrigation skate: water is made by runoff in separate paths from a distance of 0.6 m to 1.25 m; soil is leveled (slope of 0.2 to 3%);
(ii) Irrigation siphon or bordered ramps: water is beamed down by siphons or railed ramps to allow a reduction of head erosion, better flow control and consistency of water distribution (http:// www. mospi.nic.in/Mospi_New/...IRRIGATION).

Pressurized systems

(1) Sprinkler irrigation: distributing the water as rain with regulation and uniformity of the dosage given; only possible on the condition that the area does not suffer under wind with speeds over 4 m/s; systems sprinkler irrigation are either fixed or mobile;
(2) Localized irrigation: water circulates in flexible, small diameter pipes, arranged on the surface and fitted with emitting devices providing water at the plant's foot; the most prevailing localized irrigation systems are drip-irrigation (targeted at domestic audience) and micro-jet (targeted at sylviculture-market) (http:// www. mospi.nic.in/Mospi_New/...IRRIGATION).

Pressurized irrigation systems create, on average, a water savings of 30 to 60% compared to gravity-fed systems. Localized irrigation systems, in turn, can lead to water saving up to 50% compared to the sprinkler systems (limit maximum evaporation and percolation because water is delivered in un-humidified, low dosage on a fraction of the soil). Drip irrigation system is the best solution for environmentally safe, efficient and sustainable agricultural productivity for arid and semi-arid regions of the world to use scarce water resource when compared other existing methods.

Types of irrigation techniques

Objective of irrigation technique

Although various types of irrigation techniques differ in how the water obtained from the source is distributed within the field, generally, the ultimate goal is to supply the entire field uniformly with water, so that each plant has the right amount of water it needs, neither too much nor too little (Andreas and Karen, 2002).

Surface irrigation

In surface irrigation systems, water moves over and across the land through simple gravity flow in order to wet and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, border strip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land.

Localized irrigation

Localized irrigation is a system where water is distributed under low pressure through a piped network, in a predetermined pattern, and applied as a small discharge to each plant or adjacent to it. The method can be further categorized as drip irrigation, spray or micro-sprinkler irrigation.

Drip irrigation

Drip irrigation, also known as trickle irrigation, functions as its name suggests. Water is delivered at or near the root zone of plants, drop by drop. This method can be the most water efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer.

Sprinkler irrigation

In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a solid-set irrigation system. Higher pressure sprinklers that rotate are called rotors and are driven by a ball drive, gear drive, or impact mechanism. Guns are used not only for irrigation, but also for industrial applications such as dust suppression and logging. Sprinklers can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems known as traveling sprinklers may irrigate areas such as small farms, sports fields, parks, pastures, and cemeteries unattended.

Sub-surface drip irrigation

Sub-surface drip irrigation (SDI), also termed seepage irrigation, has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and thereby control the water table. Sub-irrigation is also used in commercial greenhouse production, usually for potted plants. Water is delivered from below, absorbed upwards, and the excess collected for recycling.

Drip irrigation has the potential to use scarce water resources most efficiently to produce vegetables (Locascio, 2005). The major benefits of drip irrigation are the ability to apply low volumes of water to plant roots, reduce evaporation losses, and improve irrigation uniformity (Schwankl et al., 1996). Compared to surface irrigation (flood and furrow), Sub surface drip irrigation reduce water loss to evaporation, deep percolation, and completely eliminate surface runoff (Phene, 1990), it also increase crop marketable yield and quality (Ayers et al., 1999). Use of DI can result in high nutrient use efficiency (Thompson et al., 2002). Saline irrigation water can be used with DI, while maintaining yields and improving water use efficiency compared to surface irrigation (Cahn and Ajwa, 2005; Tingwu et al., 2003). On the other hand subsurface drip irrigation applies water below the soil surface, using buried drip tapes. It has many benefits over conventional drip irrigation (Singh and Rajput, 2007). The biophysical advantages are the lower canopy humidity and fewer diseases and weeds as drip irrigation (Camp and Lamm, 2003).

Advantages and disadvantages of drip irrigation

Experimental evidences of SDI advantages over other irrigation methods, specifically drip irrigation, are vast. Some advantages and drawbacks of this method, compiled by Lamm (2002) and Payero (2005) are shown below.

Advantages of drip irrigation

The efficiency of water use is high since soil evaporation, surface runoff, and deep percolation are greatly reduced or eliminated. In addition, the risk of aquifer contamination is decreased since the movement of fertilizers and other chemical compounds by deep percolation is reduced. The use of degraded water. Subsurface wastewater application can reduce pathogen drift and reduce human and animal contact with such waters.

The efficiency in water application is improved since fertilizers and pesticides can be applied with accuracy. In widely spaced crops, a smaller fraction of the soil volume can be wetted, thus further reducing unnecessary irrigation water losses. Reductions in weed germination and weed growth often occur in drier regions.

Hand laborers benefit from drier soils by having reduced manual exertion and injuries. Likewise, double cropping opportunities are improved. Crop timing may be enhanced since the system need not be removed at harvesting nor reinstalled prior to planting the second crop. On the other hand, laterals and submains can experience less damage and the potential for vandalism is also reduced. Operating pressures are often less than in drip irrigation, thus, reducing energy costs.

Drawbacks of drip irrigation

Water applications may be largely unseen, and it is more difficult to evaluate system operation and water application uniformity. System mismanagement can lead to under irrigation, less crop yield quality reductions, and over irrigation. The last may result in poor soil aeration and deep percolation problems.

If emitter discharge exceeds soil infiltration, a soil overpressure develops around emitter outlet, enhancing surfacing and causing undesirable wet spots in the field. Timely and consistent maintenance and repairs are a requirement. Leaks caused by rodents can be more difficult to locate and repair, particularly for deeper SDI systems.

The History of drip irrigation and success

Drip irrigation has been used since ancient times. Fan Sheng-Chih Shu, written in China during the first century BCE, describes the use of buried, unglazed clay pots filled with water as a means of irrigation (http://www.brc.tamus.edu/). Modern drip irrigation began its development in Germany in 1860 when researchers began experimenting with subsurface irrigation using clay pipe to create combination irrigation and drainage systems (http://www.infoplease.com/). Research was later expanded in the 1920s to include the application of perforated pipe systems (http://www.ers.usda.gov/. The usage of plastic to hold and distribute water in drip irrigation was later developed in Australia (http://www.epa.gov/).

Usage of a plastic emitter in drip irrigation was developed in the 1930s in Israel by a water engineer Simcha Blass. He was visiting a friend in the desert when he noticed a line of trees with one member that was noticeable taller and more robust looking than the others. He did a little digging, literally, and noticed that a household water line running along the tree line had spring a small leak in the area of that one tree and as feeding it with a steady drip of water. The wet spot on the surface didn’t seem like much, but down below was a large onion-shaped area of juicy soil and modified by his son Yeshayahu (http://www.infoplease.com/). Instead of releasing water through tiny holes, which are blocked easily by tiny particles, water was released through larger and longer passageways by using velocity to slow water inside a plastic emitter. The first experimental system of this type was established in 1959 by Blass who partnered later (1964) with Kibbutz Hatzerim to create an irrigation company called Netafim. Together they developed and patented the first practical surface drip irrigation emitter (http://www.ers.usda.gov/; http://timelinks.merlin.mb.ca/). The modern development of drip irrigation started in Great Britain during World War II and continued in Israel and other countries (Camp, 1998).

Drip irrigation

Drip irrigation is the most energy and water efficient of all the irrigation systems. Water savings of up to 50% compared to sprinkler irrigation are common (Lamont et al., 2002). Ideally, water is applied in the proper amount to the root ball of the plant, minimizing water leaching from the root zone and minimizing evaporation of water since the water isn’t sprayed into the air (Shock, 2006; Lamont et al., 2002; Haman and Smajstria, 2010; Schultheis, 2005). The water can be emitted at uniform distances along a pipe or a tube with an emitter that directs water to one plant volume of soil.

The drip hose can be placed above ground or buried in the ground, which is called sub-surface drip irrigation (Lamm et al., 2003). Sub-surface irrigation has the advantage of nearly zero evaporation, but it is difficult to diagnose if an emitter becomes plugged or damaged. Drip irrigation operates at low pressures, 10 to 20 psi at the emitter. The system pressure will need to be higher to overcome pressure loss in filters, valves, backflow preventers, pressure regulator and tubing. Typically, about 40 psi is needed at the pump outlet. Drip irrigation can be designed to fit any situation or field. It can also reduce disease problems, because it doesn't get the plant wet. It does require some experience to learn how much water to apply, but a soil water sensor in the row or next to the plant can provide feedback to aid in determining the correct amount of water. Drip irrigation requires understanding of the system to assure good management and maintenance.

Drip method of irrigation helps to reduce the over-exploitation of groundwater that partly occurs because of inefficient use of water under surface method of irrigation. Environmental problems associated with the surface method of irrigation like waterlogging and salinity are also completely absent under drip method of irrigation (Narayanamoorthy, 1997). Drip method helps in achieving saving in irrigation water, increased water-use efficiency, decreased tillage requirement, higher quality products, increased crop yields and higher fertilizer-use efficiency (Qureshi et al., 2001; Sivanappan, 2002; Namara et al., 2005).

Drip Irrigation for arid soils

The classical 'leaching requirement' approach for salinity management does not work well with subsurface drip irrigation (SDI), because irrigation with SDI results in no leaching above the depth of the drip tape, and salts will accumulate throughout the growing season. Irrigation with SDI can maintain suitable root-zone salinity, but surface salt accumulation will occur unless there is adequate leaching due to rainfall or supplemental surface irrigation. Facilitating crop establishment with SDI will help to improve the long-term economic sustainability of SDI (Thomas et al., 2010).

Accumulation of salts in concentrations detrimental to plant growth is a constant threat in irrigated crop production. With surface irrigation, leaching adequate amounts of water through the soil profile (e.g. the 'leaching requirement') is the desired method for maintaining suitable soil salinity (Dasberg and Or, 1999; Hanson and Bendixen, 1995; Oron et al., 1999). By applying saline water with appropriate irrigation management techniques, long-term sustainability in agricultural systems can be achieved (Rhoades et al., 1992). One such irrigation technique is drip-irrigation, which has been successfully used in combination with saline waters (Shalhevet, 1994).

Surface drip irrigation

Wastewater recycling provides solutions for multiple problems. By recycling used water, fresh water is "freed up" for domestic needs, which is less expensive than developing new water resources. Additionally, water recycling solves waste disposal problems and reduces fertilizer requirements (Radke, 2006).

Sustainable development and reducing environmental hazards through subsurface drip irrigation (SDI) is more suitable for treated wastewater and results in even more efficient water use and crop growth than surface drip irrigation methods. However, continued research is required to ensure the success of recycled water in agricultural production.

Water management is undoubtedly the foundation of Israel's success in agriculture in arid, semiarid and dry sub-humid zones. The most conspicuous technology in this regard is the ubiquitous surface drip irrigation developed in Israel during the 1960s that enabled farmers to increase crop yield and quality while using less water and fertilizers. This result in even higher levels of water use efficiency through reduced runoff, evaporation and other parameters, and provides nutrients to plants while maintaining a dry soil surface. Drip emitters in SDI systems are positioned within the soil in attempts to conserve water, control weeds, minimize runoff and evaporation, increase longevity of laterals and emitters, permit heavy equipment to move easier in the field, and prevent human contact with low-quality water. Additional motivation for SDI comes in the form of savings of the extensive labor involved with seasonal installation and collection of surface drip system laterals (Mekala et al., 2008).

Wastewater reuse (untreated) is a common practice in developing countries of Asia and Africa and wastewater (treated) recycling is common in water scarce regions of the developed countries such as the Australia, Middle East, south west of US, and in regions with severe restrictions on disposal of treated wastewater effluents, such as Florida, coastal or inland areas of France and Italy, and densely populated European countries such as England and Germany (Marsalek et al., 2002). Utilization of SDI systems is particularly beneficial when using recycled wastewater systems, making them particularly relevant to Israeli agriculture in drylands. Whether for simple soilbased waste disposal or for agricultural utilization, regulated flow and prevention of surface exposure are extremely important when irrigation systems rely on effluents. SDI is a potential tool for alleviating problems of health hazards, odor, contamination of groundwater, and runoff into surface water. SDI particularly augments opportunities for treated wastewater in landscape and ground cover as well as in edible crops. SDI presents a unique opportunity to manipulate root distribution and soil conditions in drylands in order to better manage environmental variables including nutrients, salinity, oxygen and temperature.

The widening gap between supply and demand is often made up with marginal resources, especially reclaimed municipal wastewater, which is becoming an increasingly important source of water for agricultural in water-short countries like Israel (25% of the total agricultural water in

2000, and projected to be 37% in 2010, and 46% in 2020). The land area in Israel irrigated with treated wastewater is rising continuously- 5,100 ha in 1975, 16,300 ha in 1985, and 36,300 ha in 1994 (Dobrowolski, 2008).

Drip irrigation system components

Drip irrigation is a method of watering plants through devices called emitters. The drip emitters are usually industrially made tapes with very small outlets. Single drops of water come out at a time to wet the soil around the plants roots, hence the name 'drip irrigation'. Low head drip irrigation uses scarce water most efficiently to produce vegetables and other crops during drought periods (Alin, 2004):

1. The power unit supplies the electrical power to operate the pump if the water is coming from a well or surface water source, exclude municipal water sources.
2. Pumps are used to bring well water or surface water into the irrigation system.
3. Shutoff valves can be opened or closed to allow or prevent the flow of water into the system. Valves can be operated manually or by an electronic controller to automate irrigation.
4. Backflow preventers are one-way valves that keep contaminated water in a drip system from flowing back into the water source in the case of a sudden loss of pressure. This is particularly important if water is sourced from a well or municipal water supply.

Check with government building department or water provider to determine what backflow prevention is required locally.

5. Fertilizer injectors insert nutrients directly into irrigation water, allowing the placement of nutrients directly in the plant root zone.
6. Filters are used to remove sand and large organic particles from source water that might plug irrigation emitters. The larger the filter's mesh count, the smaller the filter screen openings. For example, a screen with a mesh count of 200 would filter out smaller particles than would a screen with a mesh size of 150. For most irrigation systems a mesh size of 15–200 is adequate.
7. Pressure regulators maintain water pressures entering the system at levels appropriate for the drip irrigation equipment. Typically, drip irrigation systems are designed around water pressures that are less than that of standard residential water pressures. Low-pressure gravity systems may not need a regulator.
8. Distribution lines carry water from the source to emitters. These can be garden hoses, UV-resistant PVC pipes or a softer material that is designed to have holes punched into it as needed.
9. Emitters and microsprayers are basic small irrigation devices used to deliver a regulated amount of water to a specific location or plant.
10. Controls are available to help automate irrigation systems. The most beneficial control device is a timer, which assists in working out of how much to water and when.

Typical timer options include AC electric timers that require access to power; DC battery timers; windup timers that require no power source; battery timers that must be manually started; and zero-pressure battery timers for gravity-fed irrigation systems.

11. Monitoring equipment should be used to assess the soil moisture levels after irrigation to ensure that sufficient but not excessive soil moisture levels are achieved. A tensiometer or similar device can be used to obtain sufficient estimates of soil moisture levels and is especially useful in situations where mulch or row cover is present (www.uaf.edu/ces or1-877-520-5211) (Figure 2).

Challenges and constraints of drip irrigation

Agricultural planning from an environmental perspective must take account of the sustainable use of non-renewable production factors which are in short supply in Israel water and soil. Land availability in the center of the country will depend on how much agricultural land is converted to residential, commercial and industrial development. Fresh water is already in short supply today both in terms of quality and quantity. Since Israel's freshwater potential will be allocated to the growing urban sector in the future, development of marginal water sources and treated wastewater will be essential to supply agricultural needs in the long term. While wastewater can and should be used in agriculture throughout the country, its quality must be upgraded and adapted to each specific use.

Wastewater and sludge utilization in agriculture must be based on the potential risks to humans, soil, crops and water sources. Israel achievements in water resources development, agricultural production and irrigation technology Israel achievements in water resources development, agricultural production and irrigation technology are still facing problems of quantity, quality and cost of water for irrigation. The system requires regular maintenance. Emitters and microsprayers can become clogged, clean water, a filtration system and regular inspection of distribution lines and emitters are essential for success. Proper emitter spacing is a must to ensure proper root development and reduce moisture stress on plants. Plants need a minimum of one emitter. Determining the duration and frequency of irrigation can be a challenge. Contamination of water sources from back siphoning can occur, and a backflow preventing device should be installed at the beginning of the system (www.uaf.edu/ces or1-877-520-5211

Major constraints among others include: Increased

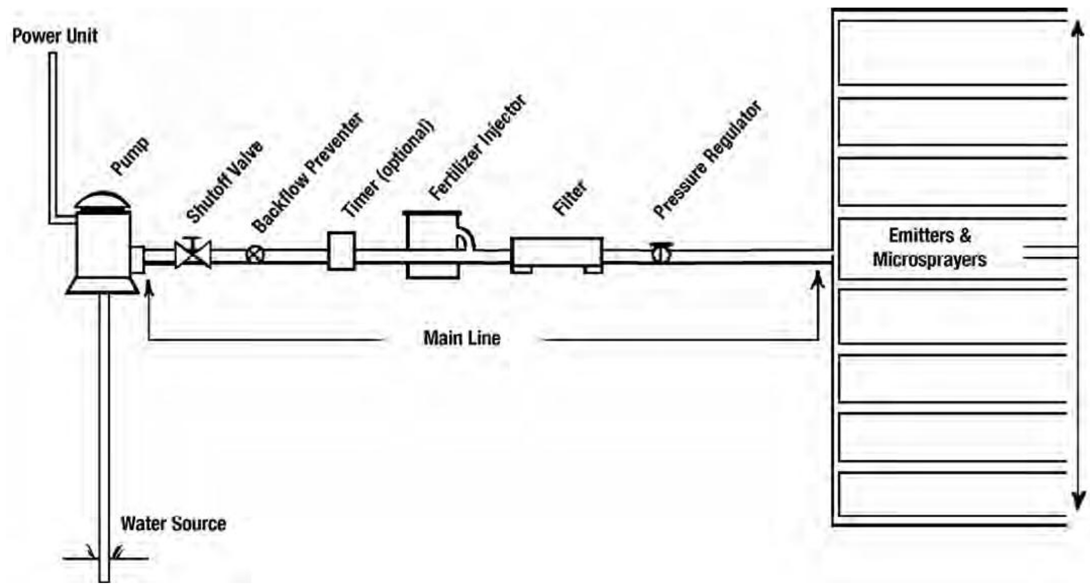

Figure 2. A schematic of lay-out and assembly order for typical drip irrigation components. Source: University of Alaska Fairbanks, 2013.

water scarcity; depleting resources, frequent droughts; degradation of water quality; technological uncertainty and high cost of non-conventional sources; rapid urbanization, abandonment and desertification of agricultural land (www.un.org/esa/agenda21/natlinfo/).

SUMMARY AND CONCLUSION

In the 1960s, drink water were used for irrigation in Israel. Recently, recycled use of waste water and nutrients fertigation have been started by mixing with water. Subsurface drip irrigation is a valuable irrigation method in arid and semi-arid regions. Drip irrigation has the highest water efficiency rate in agriculture, reaching a 70 to 80% rate, versus open irrigation, which achieves 40%. However, limited research has been conducted in the area of evaluating effects of salinity on establishment of crops with SDI in successive seasons. There is a potential for saline-water irrigation of crops in water scarce areas.

In order to achieve sustainability when irrigating with saline water, management strategies must aim to achieve two things: to minimize soil evaporation from the surface and to apply enough water to the field to ensure leaching of excess salt ions from the root-zone. Low-cost drip irrigation is suitable to use for irrigation with saline water, since it minimizes salt accumulation in the soil. As such, leaves are not subject to leaf burn, and peaks in salt concentrations are avoided. The practice of Israel drip irrigation system is the best solution for environmentally safe, efficient and sustainable agricultural productivity for arid and semi-arid regions of the world to use scarce water resource when compared other existing methods. Further research should be conducted associated with hazards to the environment and sustainable use of scarce noun renewable resources. Therefore, technology currently innovated to alleviate problem of irrigation water resources by Israel is strongly recommended to be adopted in arid and semi arid of the world to increase the productivity. Compared to other methods of irrigation system, drip irrigation has high irrigation water use efficiency. Reduced stomatal conductance and water loss formed high water use efficiency.

Conflict of Interest

The authors have not declared any conflict of interest.

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Policy interventions in watershed management: The case of the Inchaban Watershed, Ghana

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Before the twentieth century, watershed management in most Ghanaian communities relied solely on religious-based restrictions such as the use of taboos and sacred groves, to deter people from encroaching on watersheds. However, the advents of Christianity, western education, and urbanization, and the desire to develop the resources of the country have reduced the effectiveness and respect for traditional restrictions for the protection of the environment. Also, customary administration over watersheds has had a lot of challenges in evaluation and assessment of environmental damages, enforcement of laws to bring illegal land users to book, and integrating the rights of land users with policies on regulation and management. In the face of these numerous problems in the reliance on customary laws and practices, several watershed management policies have been consolidated with other key water sector policies such as the Water Use Regulation LI 1962, the Integrated Water Resource Management Policy (IWRMP) of 1996 and the National Water Vision Policy of 1997to streamline the administration over local watersheds. Despite these policies, many watersheds are still under the threat of degradation. This study identifies the reasons why the government has become unsuccessful to manage watersheds in the country. It used the Inchaban Watershed as a case, and solicited information using in-depth interviews and focus group discussions from 41 stakeholders or respondents who were selected purposively. The results of the study revealed that capacity of the management institutions to enforce the laws and policies set out by government was challenged due to problems of legal pluralism posed by local chiefs, some management and other institutions as well as individual local users of the Inchaban Watershed.

Key words: Watershed management, management institutions, user institutions, policies, Inchaban Watershed, Ghana.

INTRODUCTION

Watershed is an elevated land that separates the headwater and tributaries of one river, or drainage basin, from those tributaries flowing into another river or drainage basin (Acheampong, 2009). World Bank (2001) defines watershed as the area that supplies water by surface or subsurface flow to a given drainage system or body of

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water, such as a stream, river, wetland, lake, or the ocean. According to Pradhan (2003), watershed is that area of land within which all living things such as human beings are inextricably linked or connected to a bounded hydrological system. Watersheds are, therefore, part of human communities, and become very important for communities to properly plan their use (Pradhan, 2003). To properly plan for watershed use calls for the establishment of sound management systems.

Darghouth (2008) defines watershed management as the integrated use of land, vegetation and water in a geographically discrete drainage area with the aim of protecting and conserving the watershed resources. According to the Global Water Partnership (2000), watershed management is a process which promotes coordinated development and management of watershed resources in order to maximize economic and social welfare in an equitable manner that sustains vital ecosystems and promote conservation. Watershed management is being supported by governments of developed and developing countries including Ghana for a number of reasons. Among them are the facts that watersheds support supply of food, water and medicinal products; provide habitat for plants and animals, and regulates climate (World Natural Resource Conservation (WNRC), 1996). Manuel (2007) discovered that to meet the objectives of watershed management, there must be supportive institutional arrangements. Ostrom (1999) has subsequently suggested that institutional arrangements for watershed management should consist of organizational roles, established national laws and regulations (policies) that shape structures for human actions in order to prevent future environmental problems.

History of policy interventions in watershed management in Ghana

Before the twentieth century, watershed management in most Ghanaian communities relied solely on religious-based restrictions (Bullock, 2008) and the use of taboos and sacred groves, to deter people from encroaching on watersheds (Opoku-Agyemang, 2008).These restrictions were, to a large extent, dependent on the respect for religious, local and cultural structures for the protection of the environment (Odame, 2010).

Unfortunately, the advents of Christianity, western education, and urbanization, and the desire to develop the resources of the country have reduced the effectiveness and respect for traditional restrictions for the protection of the environment (Opoku-Agyemang, 2008). Moreover, customary administration over watersheds has had numerous challenges in evaluation and assessment of environmental damages, enforcement of laws to bring illegal land users to book, and integrating the rights of land users with policies on regulation and management (Gibson, 2001).

In the face of these numerous problems in the reliance on customary laws and practices, the government of Ghana resorted to the enactment of state laws and policies to strengthen mandates of institutions in charge of managing water resources. The first comprehensive attempt to regulate the use of water resources, other than for industrial production activities, was the enactment of the *Rivers Ordinance Act (CAP 226) of 1903*. Section 10 of this Ordinance states that it shall be unlawful to pump, divert or by any means cause water to flow from any river, for purposes of large scale irrigation, mining or to generate power without a license from the appropriate quarters.

Unfortunately, there was no follow-up to the Rivers Ordinance Act. Consequently the ordinance was overtaken by time and other enactments which contained specific provisions that enabled agencies to perform certain functions, some of which were watershed-related (Bossman, 1998). For example, the *Forestry Ordinance of 1927* made provisions for catchment protection and control of water abstraction in forest reserves. The *Land Planning and Soil Conservation Ordinance of 1953* contained sections for checking soil erosion and the control of watercourses. State laws were very beneficial to some extent since they stressed the need to establish institutions and agencies to support watershed management (Odame, 2010).

The onset of the post-independence era opened the way for the establishment modern policies with specific legal enactments for water supply and drawing of economic products in watersheds. Table 1 shows some relevant watershed management policies and their associated legal enactments. As observed by Opoku-Agyemang et al. (1998), Table 1 demonstrates the attempts made by previous governments to improve watershed management by some agencies in Ghana. For example, to promote sound cooperation among water resource users and managers, *the Integrated Water Resource Management Policy (IWRMP)* was formulated and implemented in 1996. Five years after, the Water Use Regulation LI 1962 Policy was then implemented to streamline the administration and governance over local water bodies which were under serious threats of degradation. Realizing the weaknesses in the earlier policies, the National Water Vision Policy was formulated and consolidated with other key water sector policies to comprehensively manage the nation's water resources.

The attempts by government of Ghana was to emulate successful watershed management policies such as that of Restoration of the Alps of the United States, Integrated Soil and Water Management (ISWM) in Brazil, which were used for rehabilitation, restoration and conservation of watershed resources (Maarleveld and Dangbegnon, 1998).

However, in spite of all these policies and regulations, the Inchaban Watershed in the Western Region of Ghana is still under the threat of degradation. The Inchaban

Table 1. Watershed management policies formulated by the Ministry of Water and Housing (MWH).

Date formulated	Policies formulated	Goals to be achieved
1996	Integrated Water Resource Management Policy (IWRMP)	To promote sound cooperation among water resource users and managers
2001	Water Use Regulation LI 1962 Policy	To streamline the administration and governance over local water bodies
2006	Drilling for Water and Groundwater Development Regulation Policy LI 1827	To license drilling companies and ensure safe development of watershed resources
2007	The National Water Vision Policy	Being consolidated with other key water sector policies to comprehensively manage the nation's water resources
2012	The National Buffer Zone Policy	To initiate the development of programmes to safeguard watershed resource.

Source: Ghana Ministry of Works and Housing, 2010.

Watershed is degraded due to a number of anthropogenic factors such as expansion of cultivated areas, unsustainable fuel wood and timber harvesting, bushfires, and the development of settlements and other infrastructures (Carson, 1992). For instance, according to Button (2010), the rate in which the Inchaban watershed is built-up is 7.6% per year. The increasing encroachment of the watershed has adversely affected economic activities such as fishing and farming. For example, the quantity of charcoal production, a major economic activity of the inhabitants, dropped by 30% between 2007 and 2009 (Biney, 2010). This raises a number of questions about the adherence to the policies set out by government (Table 1) to support the institutions responsible for managing the Inchaban Watershed. It is against this background that this study seeks to identify the approaches and the challenges against the effective use of policies set out by government to effectively manage the Inchaban watershed. The subsequent sections look at the conceptual framework of the study followed by the methodology and analysis of results.

Conceptual framework

The integrated watershed management framework: IWM-framework

The Institutional Framework for Integrated Watershed Management developed by the Water Resource Commission of Ghana (WRC) has been adopted for this study.The choice of this conceptual framework for this study is informed by the definition of integrated watershed management as a comprehensive multi-resource management planning process involving all stakeholders within the management processes. Stakeholders in watershed management are expected to work cooperatively to identify an approach that is environmentally friendly and economically sustainable (Botero, 1986; United Nation Environment Programme (UNEP), 2004). In the framework, the WRC is the superior body empowered by an *Act of Parliament (Act 522 of 1996)* to grant rights to watershed users to allocate watershed resources, and to implement policies. The strength of this framework (Appendix Figure 1) is that it spells out clearly the processes to govern watersheds in terms of policy formulation and implementation. The IWM-framework designed by Water Resources Commission (WRC) was tailored to address the diffused functions and authority of institutions concerned with water resources management with the aim of integrating their roles, objectives, mandate, policies and laws. Going by this framework, the National Development Planning Commission (NDPC) and the Ministry of Works and Housing (MWH) are expected to work in collaboration with the WRC to specifically coordinate national development plans and also formulate national water policies. The WRC supervises the activities of key representative groups that are involved in water services delivery and utilization. These actors are the Water Research Planning Input Providers, Water Users, Regulatory Agencies and Civil Society Representatives. The roles and activities of the representative groups are summarized in Appendix Figure 1.

METHODOLOGY

Study area

The Inchaban Watershed is located in the Shama District of the Western Region of Ghana (Figure 1). The size of the watershed is 13,553.80 acres. The climate is dry-humid tropical (Acheampong, 2009), and has a double maximum rainfall; the main rainfall season lasts from June to early August, and the minor from September to November. The average annual precipitation is 1195 mm (Acheampong, 2009). The dry season is short, occurring from

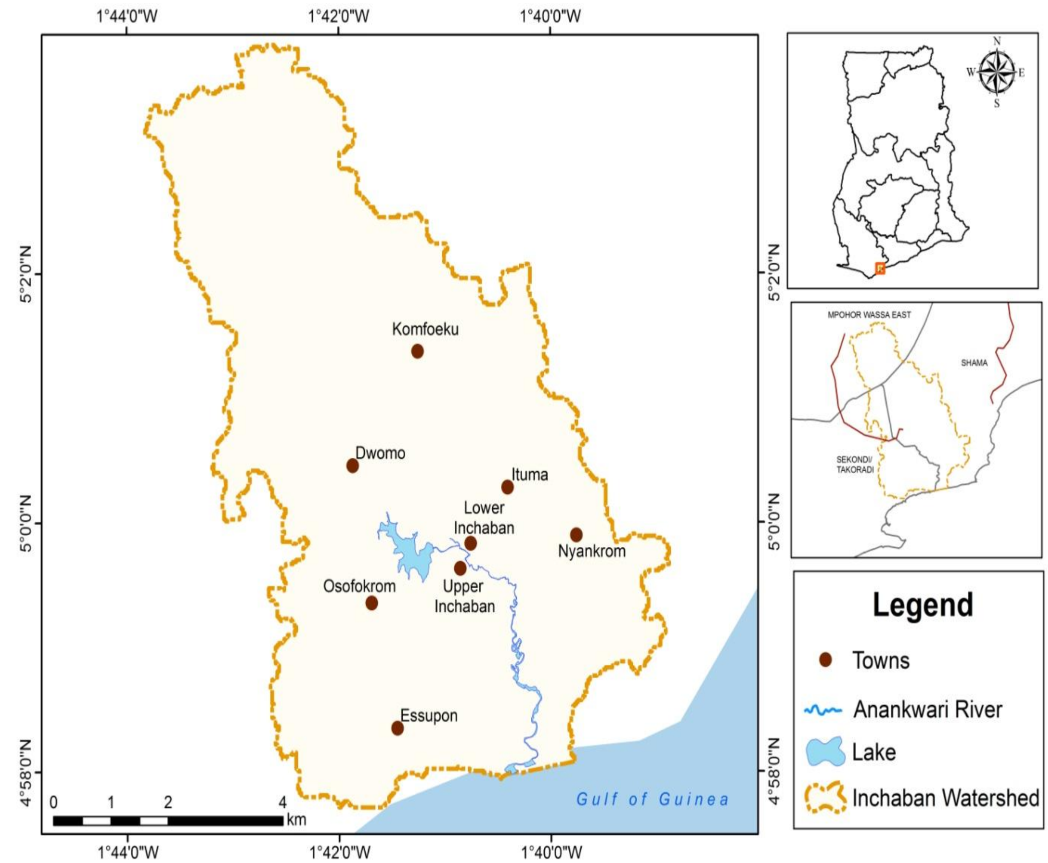

Figure 1. Map of the Inchaban Watershed. Source: Cartography Unit of the Department of Geography and Regional Planning (UCC), 2011.

December to February. The average annual humidity of the area is high (over 94%) and the mean annual temperatures are 29°C. The main vegetation in the watershed consists of woodland savannah near the coast, while a semi deciduous forest occupies the upper courses of streams. Mangroves occur along the southern portion of the watershed. The nature of the climate and vegetation of the district has limited the growth of most local food crops but rather sugar is extensively cultivated. Consequently, mining and charcoal burning activities have absorbed about 45% of the active labour force. Many pockets of farming activities occur in communities such as Dwomo, Nyankrom and Ituma whereas charcoal burning activities have been intensified in portions of the watershed at Inchaban.

The relief of the study area is undulating, gently sloping towards the coast, and is interspersed with plains in the west. The landscape is characterized by muddy lagoons and marshlands as a result of the undulating topography. The district is drained by River Anakwari. River Anakwari is dammed at Inchaban to supply potable water to Takoradi and its surrounding settlements that include Dwomo, Nyankrom, Ituma, Shama and Yabiw. Drainage in the district is very poor; the area is prone to flooding.

Research design

The descriptive research design was used in the study. This research design incorporated scientific methods which involved observing and describing the behavior of respondents without influencing them in any way (Creswell, 2003). The method helped to describe the social systems, social events and background information related to the study. It also helped to stimulate explanations (Sarantakos, 1998). This method as observed by Hakim (2000) is the best because it helps to give a thorough picture of a phenomenon, and the changes that have occurred in a phenomenon over time.

The study population

The target population comprised all the state user and management institutions, non-governmental organisations (NGOs), local authorities and individuals who engage in economic activities in the watershed. The relevant state institutions identified were the Water Resource Commission, the Environmental Protection Agency (EPA), the Forestry Commission (FC), the Mining Commission (MC), the Hydrological Service Department (HSD) and the Water Resource Institute (WRI) of Ghana. The non-governmental organisations were the Coastal Resource Centre (CRC) and the Friends of the Nation (FON). The state user institutions are the Irrigation Development Authority (IDA), the Ghana Water Company Limited (GWCL), the Community Water and Sanitation Agency (CWSA), the Mining Commission (MC), the Ministry of Food and Agriculture (MoFA) and Hydrological Service Department (HSD). The individual respondents comprised residents from three selected communities which were Ituma, Inchaban and Dwomo (Figure 1).

Table 2. Total sample size for the study.

Sample units	Sample size
Watershed management organizations	4
Watershed user organizations	4
Community chiefs	3
Individual users	
Crop farmers	9
Charcoal producers	12
Fishermen	9
Total	41

Sampling procedure

Two non-probability sampling methods were used to select the respondents: The purposive and convenience sampling methods. The purposive sampling technique was first used to select the chief of three settlements (Inchaban, Ituma and Dwomo) from a total of eight settlements (Komfoeku, Dwomo, Osofokrom, Essupon, Yabiw, Ituma, Nyankrom and Inchaban, within the watershed. The chiefs were selected because their subjects were engaged in economic activities in the watershed, and can therefore be in the position to provide relevant information to the study. Four organisations (EPA, FC, WRC and CRC) were selected from a total of seven watershed management organisations that were the Environmental Protection Agency (EPA), the Forestry Commission (FC), the Mining Commission (MC), the Hydrological Service Department (HSD), the Water Resource Commission, the Water Resource Institute (WRI) and the Coastal Resource Centre (CRC). The four selected management institutions were identified to be active, and each entrusted with different duties in the management of the watershed. Hence, each of them could provide unique information relevant to the study. Four watershed user institutions (IDA, GWCL, MOFA and CWSA) were also selected from a total of six user institutions that were the Irrigation Development Authority (IDA), the Ghana Water Company Limited (GWCL), the Community Water and Sanitation Agency (CWSA), the Mining Commission (MC), the Ministry of Food and Agriculture (MoFA) and Hydrological Service Department (HSD). The two institutions: MC and HSD that were not selected were observed to be dormant. The selected user institutions were identified to be active and engaged in several different economic activities in the watershed. As such these selected user institutions could provide useful information to the study. Additionally, the convenience sampling technique was used to select nine crop farmers out of 15 in Ituma, 12 charcoal producers out of 16 in Inchaban and nine fishermen out of 15 in Dwomo. Focus group discussions (FGDs) were conducted for these individual users in their homogeneous groups from the above-mentioned villages (Ituma, Inchaban and Dwomo). Therefore, in all, a total sample population of 41 was used in the study (Table 2)

Data collection instruments and techniques

The data collection instruments employed consisted of three (3) sets of in-depth interview guides, three sets of focus group discussion guides and an observation checklist. The in-depth interview guides containing a number of unstructured questions were each used to collect data from the chiefs in the three settlements, from the management institutions and from the user organisations respectively. The set of questions in the in-depth interview guides elicited responses on issues regarding the background characteristics of respondents, effectiveness of the approaches and the challenges confronting the management institutions responsible for managing the Inchaban Watershed.

Three sets of focus group discussion guides (Appendix 2) were used to collect data from individual users (farmers, fishermen and charcoal producers) of the watershed (Table 2).

Data processing and analysis

The data collected was conceptually organized into themes which were based on the objectives of the study such as assessment of the effectiveness of the approach used to manage the Inchaban Watershed and the challenges of the management institutions to implement policies set out by government and analyzed manually, while the data collection was still on-going. This method was employed so as to intensify probing into issues on more specific aspects of the objectives of the study. Again, the analysis during the data collection was important because it guided the study to facilitate a more effective treatment and coverage of the research topic (Benini, 2000). Conclusions drawn after the analysis were tested against notes and records from the field.

RESULTS AND DISCUSSION

The results of the study under the following sub-headings:

1. Assessment of the effectiveness of the approach used to manage the Inchaban Watershed
2. The challenges of the management institutions to implement policies set out by government.

Assessment of the approach used to manage the Inchaban Watershed

Focus group discussions (FGDs) to assess the management approach with the key societal groups in the local communities surrounding the watershed revealed that there have been several discussions with the individual users on best farming practices. Farmers, for example, had understood very well the concerns of the government about the conservation of the watershed. Indeed the chiefs of the settlements admitted that they had been involved in the discussions on planning and implementation of projects such as contour farming, vegetative barriers and earth bunds to erosion control. Interviews with the chiefs of settlements in the watershed agree with the bottom-up approach used in managing the Inchaban Watershed. This falls in line with the findings of Thoruw and Juo (1995), who made the observations that the first among the local authorities to confirm the practice of the bottom-up approach was a chief of one of the communities who recalled that:

"Officials from almost all the management institutions come to me to solicit my views on a number of projects to conserve the watershed. I quickly invite the leaders of the Crop Growers Association, and schedule time to meet the other farmers in the field. Agreeably, we meet the

farmers about a week or two, and have discussions on a few projects such as contour farming, vegetative barriers, and earth-bunds projects. The officials also educate the farmers and take some of their concerns to government for policy formulations." (Village chief, Inchaban Watershed)

Even though the bottom-up approach was started, for it to be successful, according to Leach and Sabatier (2002), local people are expected to be involved in important stages of the project cycle such as monitoring and evaluation. Leach and Sabatier (2002) further made the observations that participatory watershed planning must go beyond initial implementation of policies to yield good results. However, the focus group discussions with the individual users and chiefs indicated that the watershed institutions never made any special arrangements to involve the local people in monitoring projects. By implication, as identified by Martin (2008), the management institutions find it difficult to arrest free-rider behaviour among the individual watershed users. As a result, the management institutions such as EPA and FC could not evaluate projects such as tree planting, protection of river banks, protection of land from erosion, soil fertility projects, contour farming projects, vegetative barriers and earth bunds projects, land and water management projects, among others to reshape subsequent plans based on future impacts of the projects in the watershed. Instead, the management institutions resorted to a simple method of tasking some untrained influential members to provide security for implemented projects. With this approach, according to the charcoal producers, the institutions never hadgood feedback to assist them to redesign future projects.It therefore, became difficult to discourage negative practices on the watershed. One of these charcoal producers had this to say:

"The EPA and the FC came to plant some trees in the watershed in 2008. The officers in the management institutions had made fruitless attempts, over the years, to arrest illegal users because they relied on people from this community to provide security for their projects. It will be very advisable for some of the officers to come and live with us here to make their work effective" (Charcoal producer, Inchaban Watershed).

More importantly, the suggestions of the local communities were expected to reach top management authorities on time for quick implementation of projects and granting of watershed use rights. However, the user institutions and individual users complained that it took them about half a yearbefore their concerns were sent to the WRC. Additionally, the users of the watershed who had been convinced to accept the bottom-up approach complained about the bureaucracies involved to obtain permission from the top officials. For example, the district head of the Irrigation Development Authority (IDA), who had had several confrontations with the heads of the National Development Planning Commission (NDPC) and Water Resources Commission (WRC), in the course of obtaining permission for the local users for crop farming irrigation, poured out his sentiments about the management system as follows:

"We expect our higher authorities (NDPC and MWH) to submit our development plans to the WRC on time for quick feedback. Unfortunately, since 2005 we have not been given authority to grant permission on any project plan sent to the NDPC especially" (District Head, Irrigation Development Authority, Inchaban Watershed).

According to Sabatier et al. (2002), for successful watershed management, top managers are supposed to, in addition to existing policies; spell out other management policies without delay to allow needful economic activities. Findings from the study indicated that this was not the case. It was found out that the top managers (MWH, NDPC and WRC) of the Inchaban Watershed did not have policies to allow local users to conduct economic activities. Hence, the bottom-up approach was not attractive to local users.

Sectoral approach of watershed management

In other interviews, the heads of the selected institutions admitted that most of them had implemented programmes with different priorities regarding the management of the Inchaban Watershed. It also followed that the user and management institutions had, in addition to bottom-up approach, started using the sectoral management approach. These results fall in line with the findings of Pretty and Shah (2000), where watershed management agencies implement programmes according to their own targets and priorities.

Following the sectoral management approach, it was discovered that the Ghana Water Company Limited (GWCL) confined its operations to the improvement of the quality of water from the watershed. Whereas the Environmental Protection Agency (EPA) implemented projects such as the Invasive Aquatic Water Project, Water Hyacinth and Lettuce Projects towards protecting aquatic life in River Anakwari. The interviews again revealed that the Ministry of Food and Agriculture (MoFA) and the Irrigation Development Authority (IDA) had been focusing on soil rehabilitation projects. Incidentally, the management institutions had followed the national development plan that had a specific goal of conserving the watershed but took operations with different objectives, making them unsuccessful. With the fast depletion of the Inchaban Watershed, the heads of the management institutions expressed displeasure in the sectoral approach, and therefore proposed for the establishment of joint projects that will involve all the stakeholders who matter in managing the watershed. This will help take into consideration the views and opinions of all affected groups, users and individuals who use the Inchaban Watershed. When this is done, the concept of integration and better sustainability of watershed resources will be enhanced (Ozyuvaci, 1997).

On the other hand, the individual users of the Inchaban Watershed rather embraced the sectoral management style because they realized that when the institutions worked independently, they had a leeway to take permission from any of them (the institutions). For example, the local charcoal producers commended the Forestry Commission (FC) for supporting them with ideas and strategies to increase their production using the Acacia trees from the watershed. A fourty-year old charcoal producer had this to say:

"We are highly indebted to the Forestry Commission; the institution has, over the years, supported us with permission right to use the Acacia trees in the watershed. It is good that the Ghana Water Company Limited had concentrated on the management of water in rivers and left the forest trees for the Forestry Commission to manage. Taking separate functions like this will help to conserve the watershed" (Charcoal producer, Inchaban watershed).

In another instance, the crop farmers in a typical farming community (Ituma) in the watershed commended the Irrigation Development Authority (IDA) for educating them on soil conservation strategies. One of them at Ituma frankly said:

"Since 2000, we have had several supports from the IDA. Most at times, the IDA supplies us with equipment such as water pumps and cutlasses for cultivation to prevent soil erosion. The IDA also organizes workshops on projects for soil rehabilitation to support our work" (Crop Farmer, Ituma Village, Inchaban Watershed).

In summary, the FC, the GWCL and the IDA concentrated on the management of the forest trees, rivers and the soils in the Inchaban Watershed respectively. These findings conform to the results by Economic and Social Commission for Asia and the Pacific (ESCAP) (1997) when they assessed the use of sectoral management approach in the success of the Mahaveli Project Schemes worked on by state institutions in Sri Lanka.

Challenges to the implementation of watershed policies

Challenges related to coordination among the management institutions

The WRC, MWH and the NDPC operate at the top level of decision-making and are expected to coordinate the activities of the FC, EPA and the CRC to prevent conflicts with the user institutions (IDA, CWSA, GWCL and MoFA) (Amakye, 2002).

Here, we assess the level of coordination among the institutions at the top level of decision making and allocation of watershed resources. Interviews with the head of the WRC showed some level of collaboration among the institutions (WRC, MWH, and NDPC). For example, the head of the WRC had policies (Table 1) that the MWH and the NDPC respectively, had designed to support its (the WRC) work. Better still, we also assessed the extent to which this collaboration had gone. Further discussions on management duties with the head of the WRC revealed that the WRC had failed to take up subsequent follow-up duties with the NDPC and the MWH, to ensure that policies and laws instituted were being obeyed by the local users of the watershed. This shows a poor collaboration between these institutions (NDPC, MWH and WRC).

Social challenges

One realizes that as population grows, societies become dynamic and it calls for a review of laws and policies governing resources use (Heckathorn and Maser, 2001). In interviews with the local people concerning resource use in the watershed, it came out that there were illegal building construction, illegal agricultural encroachment and large-scale illegal logging in the Inchaban watershed (Plate 1). Such practices have been vehemently fought against by the management institutions such as the EPA, FC and WRC offices in the area by the use of prohibitive laws such as the use of land guards in protecting the forests, use of taboos, vegetation cannot be cleared along a strip of 30 m at both banks of streams and rivers and days and periods when fishing, farming and hunting are prohibited or forbidden. Yet, since 1996, the Ghana WRC had approved the 'Integrated Watershed Management Policy' which allows diverse uses of all watersheds in every region. Thus, the prohibitive laws contradict the policy of the government to promote the concept of integrated watershed management.

This meant that, with increasing demand for land for settlements and other private uses such as farming and construction of buildings, the work of the NDPC and MWH was to collaborate with the WRC to re-formulate policies that could permit urgent uses of the Inchaban Watershed in order to follow the approved management approach. Without any options for land for survival such as for farming, fishing and charcoal, the individual users buy watershed usage rights (rights to enter, right to use, right to take wood or selling the land out) from the government institutions. In an in-depth interview with the head of the WRC, some explanations were given about the institution's reluctance to allocate the watershed resources to the local users. This is what the head of the Water Resource Commission had to say:

Plate 1. Acacia trees cut down in the Inchaban Watershed. Source: Fieldwork, June 2012.

"We cannot permit all users including individuals to use the watershed because the watershed vegetation is fast depleting. We normally give priority to state institutions like the IDA, GWCL and CWSA. We had entrusted the use of the watershed to the state institutions whose activities are environmentally sustainable and in the interest of the entire society. Unfortunately, individuals rather get the chance to work on the lands demarcated. We have the information that some of the state institutions have sold their usage rights to these individuals but we find it difficult to prosecute them" (Head, WRC, Inchaban Watershed).

Legal capacity challenges

The *Water Use Regulation Act of 1962*, supports the integrated water resource management policy of Ghana, and gives WRC the mandate to regulate the use of all water bodies in the country. To make the work of WRC easier, the EPA, FC, NGOs and local authorities have also been assigned specific and separate roles to support the WRC to manage water bodies. Serious conflicts were detected among the local management and user institutions. The local chiefs in the first place, said that the state management institutions did not give them room to exercise their powers. From the *Statutory Land Administrative Act 125 of 1962* of Ghana, power is only given to the WRC to plan and manage watersheds and the subordinate institutions and civil society organizations such as the local chiefs are to conform, not exercise power. The chiefs recalled instances where they had given permission to some of the farmers and fisher folks to use the watershed, and have been chased away by the management institutions. For example, the queen mother of one of the communities made it clear that it was time they claimed portions of the watershed to support local economic activities. This is what she said:

"In colonial times, portions of the Inchaban Watershed were demarcated for our forefathers to use. It is just about time we reclaimed the lands that belong to us to support the local people here. We will not sit down and watch other people to use the watershed illegally. I have written several letters to take permission from the management institutions for the local users of the watershed but have not had any good feedback. Personally, I grant some of the local people usage right when they ask for help. I know they receive threats from the government authorities but we still support them in every way" (Queen Mother, Inchaban Watershed).

The *Statutory Land Administrative Act 125 of 1962* of Ghana supports the state watershed management institutions to regulate and control the use of all lands such as mineral sites, forest lands and water bodies that fall under the areas of interest of the state (Opoku-Agyemang, 2001). For state watershed management institutions to work effectively, government of Ghana has established institutions as the Lands Commission, the Survey, Town and Country Planning Department and the judicial courts to support the state's claim for lands for social development. However, the reports obtained from the management institutions showed that the state judicial system, unfortunately, is weak to support governance over the Inchaban Watershed. In most cases, the reports were that certain institutions took bribes from individual users and overlooked the illegal activities in the watershed. Others have also supported some political leaders to erect structures for self-owned businesses in the watershed. To make the situation worse, as was indicated by an official of the Environmental Protection Agency, the judicial courts went on adjourning cases involving illegal users of the Inchaban Watershed. He said frankly that:

"Since the last four years we have sent three major cases to the courts requesting the support of the Takoradi Court to stop the construction of buildings in the watershed. As I speak to you, there are two additional cases of illegal construction in the watershed. The courts kept on adjourning the hearing of these cases. We have persistently referred the cases to the local chiefs for support but, to our dismay, the chiefs go behind us to encourage the illegal users of the watershed. Some of the heads in the other sister watershed management institutions pay bribes to the court officials for the cases to be adjourned" (EPA official, Inchaban Watershed).

The poor cooperation among the management institutions posed legal challenges for the institutions to battle with. Once the management institutions neglected collaborative project building and thus followed, to a large extent, the sectoral management approach, there were always conflicting interests that resulted in serious legal challenges.

CONCLUSIONS AND RECOMMENDATIONS

Two main approaches (the bottom-up and the sectoral approaches) were discovered to be in use for the management of the Inchaban Watershed. The bottom-up approach was least practiced due to challenges of getting community support after the project implementation (to conserve the Inchaban Watershed). Also, the results obtained in this study indicated thatthere was not regular monitoring and evaluation by the management institutions to ensure successful project implementation. Again, there was limited involvement of the local community in important stages of the project cycle such as the monitoring and evaluation phase. These were challenges to the smooth and successful practice and adoption of the bottom-up approach in watershed management of the Inchaban watershed. Also, the sectoral management approach was adopted due to the fact that management institutions concentrated on different aspects of the watershed in order to conserve it.
Assessment was also made of the institutional linkages among the top watershed management institutions to see how best the policy of integrated watershed management has been implemented. Findings from the study indicated that the NDPC and the MWH collaborated poorly to support the work of the WRC. The NDPC and the MWH had only formulated watershed use policies and coordination of projects respectively but have neglected important follow-up duties to ensure that the policies are being implemented and enforced. Little has been done about monitoring, evaluation and assessment of the achievements over the years. The linkages between traditional authorities such as chiefs and management organizations (EPA, FC, WRC and CRC) were also poor and this poses legal challenges. The mandate of watershed management institutions supported by the *Watershed Resource Act 522 of 1996* though has been stated clearly in the Customary Land Administrative Policydocument (this document supports Ghanaian local chiefs to manage local and indigenous resources). It appears this document is not known to many chiefs and other traditional leaders.

In connection with the key findings and conclusions drawn, the following recommendations have been made:

1. Government should ensure better implementation and fixing the problems in the current policies or there should be system to promote sound institutional arrangements among the watershed management institutions responsible for the Inchaban Watershed.
2. It should be the policy of the government to educate local authorities to constantly support the operations of watershed management institutions.
3. To attract the participation of the communities surrounding the watershed, there is the need for building the capacity of government institutions in implementing more participatory, multi-stakeholder approaches to watershed management".

Conflict of Interest

The authors have not declared any conflict of interests.

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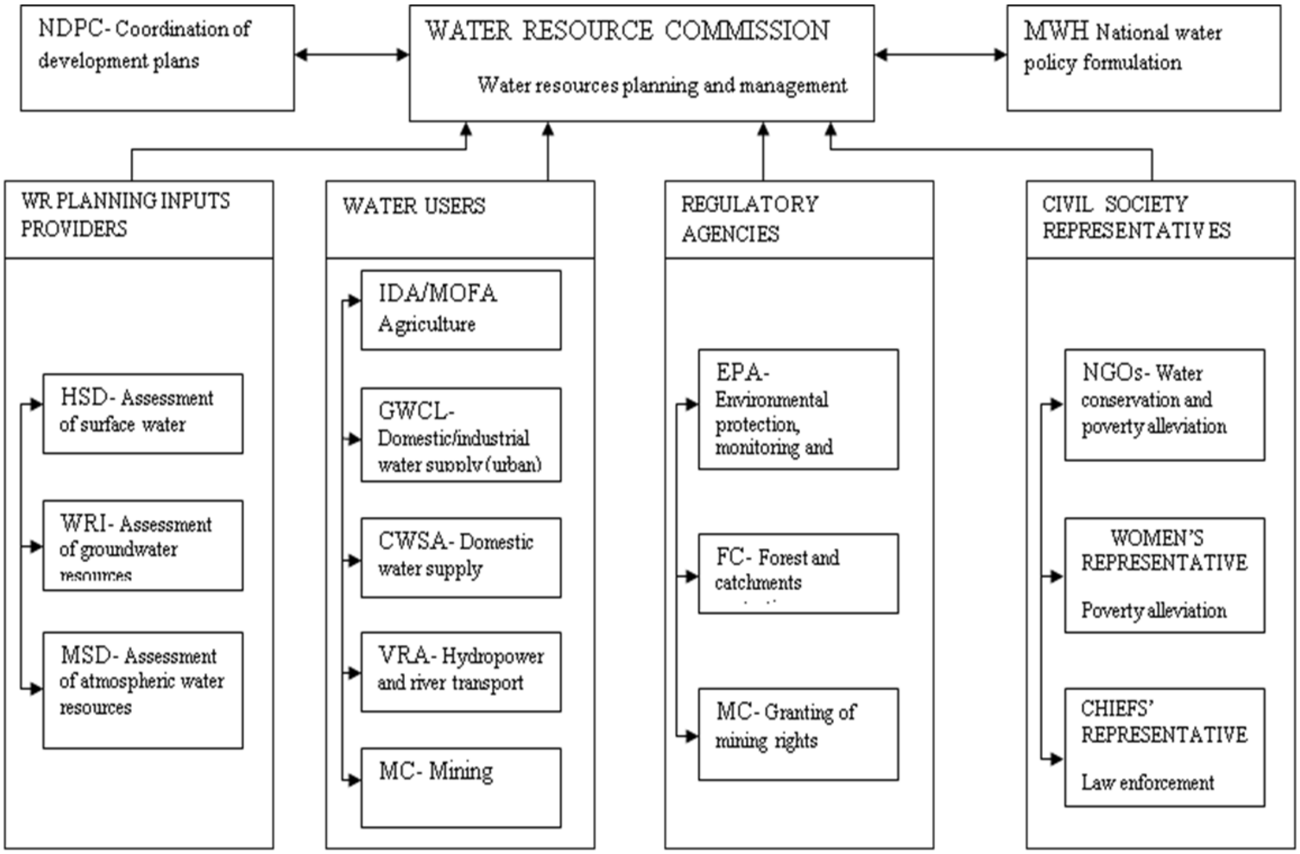
APPENDIX



Appendix Figure 1. The Integrated Watershed Management Conceptual Framework. Source: Ghana Water Resources Commission, 2000.

Appendix 1: The Integrated Watershed Management Framework. Source: Ghana Water Resources Commission, 2000

Appendix 2: Focus group discussion guide for crop farmers, fish farmers and charcoal producers

Date of interview:
Place of interview:
Interviewer name:
Time of interview:

The main objective of the study is to examine the institutional arrangements in managing the Inchaban Watershed. The study is primary for academic work, and therefore you are assured of full confidentiality, privacy and anonymity of all the information that you will give. Please or kindly answer each question to the best of your ability by providing responses that best reflect your opinion.

Section A: Watershed management approach

1. Mention some of the organisations in charge of managing the watershed. Probe: What roles do they play?
2. Do the government authorities involve you in managing the watershed? If Yes, Probe: Where is involvement done? Indecision making, formulation of management policies, implementation of project policies, monitoring and evaluation.
3. What are some of the projects initiated in your community to manage the watershed? Probe: The nature of the projects (e.g. terracing, tree planting etc), when the projects were started, which organisation initiated the projects, challenges encountered in starting projects, success stories of projects. Are the projects done jointly by individuals and government organisations, or are the projects done jointly by NGOs and government organisations?
4. Do the organisations have different management activities which concentrate on different aspects of the watershed (use the sectoral approach)? If Yes, Probe: Type of activities (e.g. contour-bunding, landslide fencing, gully control, plantation growing, etc.), times that the departments do such activities, aspects of the watershed (e.g. forest, land or water) that the activities are aimed at, challenges encountered in this approach, advantage of this approach.

Section B: Economic activities of user organisations and their effect on the economic activities of local inhabitants

1. What are some of the economic activities that user organisations undertake on the watershed? Probe; farming, fishing, sand winning, (any other?, Please specify).
2. What products do they obtained from the watershed? Probe: (a) Food; which kind (cereals, grains, tubers, etc.), how do the activities of user organisation affect your output level (increase or decrease by how much). What is the quantity? (b) Employment; what type of employment, how does the activity of user organisations affect the security of your job, are there any other sources of employment?
3 Do the user organisations have any alternative source instead of using the watershed?

Section C: Activities of watershed management organisations and their effects on the economic activities of the people

1. What are some of the conservatory activities of the management organisations? Probe; tree planting, terracing or contour "bunding", (any other?)
2. How does the activity of the management organisation affect the following. Probe: (a) Food, which kind (cereals, grains, tubers, fish etc.) how does the activity of user organisation affect your output level (increase or decrease by how much); what is the quantity. (b) Employment, what type of employment, how does the activities of user organisations affect the security of your job, are there any other sources of employment?
3. Do the user organisations have any alternative source instead of using the watershed?

Section D: Assessment of the drainage basin management institutions on the principles of transparency, accountability and participation

1. Transparency (openness of governance processes and free access to official information): Are there available information about who, how and what decisions are made at the district assembly level? Probe (If yes, is the information available in a format and language that is easily understood by non-experts, accurate and up-to date? Is the information timely (that is, was it available prior to key decision-making processes such as planning, a town-hall meeting or available websites or on public notice boards); How long does it take to get the information?
2. Accountability (a set of controls, counterweights and supervision modes that make officials and institutions in the public and private sector answerable for their actions): Are there internal control mechanisms, checks and balances within the drainage basin management institutions to ensure internal accountability. Probe: Are there monitoring and evaluation institutions that ensure to check the services provided by the drainage basin management institutions? Is there an independent body that oversees and monitors state institutions to ensure that established norms and standards are met? Has the state oversight institutions got the legitimate power to demand accountability on both fiscal management and performance of management institutions? Are there laws, rules and regulations that govern the accountability relationship between oversight institutions?
3. Participation (the possibility for citizens to provide informed, timely and meaningful input and influence decisions at various levels): Are there mechanisms for citizens to express themselves and influence decisions and processes in the management of drainage basin? Probe: Are your decisions being heard and taken into consideration during town hall meetings? If Yes to Question 3 at which stage are you given the opportunity to make suggestions to the management of the drainage basin?

Formulation of management policies [ ] Often [ ] very often [ ] not often [ ]
Implementation of project policies [ ] Often [ ] very often [ ] not often [ ]
Monitoring and evaluation [ ] Often [ ] very often [ ] not often [ ]

In each case indicate how often (the opportunity is given decision making (Often, Very often, Not Often).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