WATER RESOURCES FOR AGRICULTURE AND FOOD PRODUCTION

C. Him-Gonzalez
Universidad de Panamá, República de Panamá

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1. Introduction

Water resources have been historically regarded as essential for a good agricultural output and adequate food supply for the people. All ancient civilizations that have prospered developed successful water resources management schemes. Water resources for agriculture and food production are classified as either surface or underground water. In humid climates surface water is the main source for irrigation systems. Under sub-humid and arid conditions, underground water is the major water resource for agriculture and food production.

Water in the form of rain and snow is made available by nature in the yearly hydrological cycle. Precipitation is even intercepted by the vegetation, infiltrated into the ground or runs off as runoff. From infiltrated amounts, a sizeable part goes to evapotranspiration for biomass generation. Another part percolates into the water table feeding natural aquifers. Surface runoff concentrates in channels that drain into larger channels making up a watershed drainage network that discharge into the sea or is stored in lakes or dams. Water is recycled continuously through transpiration, evaporation from land, river systems and oceans. A watershed or river basin is a natural entity that should be used as an integrating unit for water resources planning.

Precipitation, withdrawals and availability of water vary widely around the world. Per capital availability is highest in Latin America and lowest in North Africa and the Near East while withdrawals are highest in North America and lowest in Africa. Per capital water availability in Europe and North America is not expected to change greatly by 2000 while Asians, Africans and Latin Americans will face less per capital water availability as their populations continue to grow. The present global water use for agriculture and food production is about 70% of the total. As demands rise in all the sectors, availability problems will enlarge. The potential water resource available in various regions and countries to meet the requirement of 2025 is extremely varied.

It is estimated that while the population will grow from 6 billion to 8 billion in next 25 years, the present food production shall have to be doubled. Under this conditions, food needs will exceed projections of agricultural output. Large-scale farming could not provide food for the world's large populations without the irrigation of crop fields by water sources from rivers, lakes, reservoirs, and wells. Without irrigation, crops could never be grown in the Imperial Valley of California, the Irrigation Districts of Mexico or the deserts of Israel.

According with the Food and Agriculture Organization of the United Nations, FAO (1998), demands for water for growing more food will increase causing shortages in regions that up to know are self sufficient in water resources. The growth in shortage could be avoided only by developing the potential sources or by decreasing the withdrawals and simultaneously increasing water use efficiency. Countries with large populations are trying their best for maintaining self-sufficiency in food production. In this countries in case of droughts, the shortfalls will be too large to be covered by world trade due to financial constrains and food trade availability. Given these facts, it is clear that food security in the XXI century will is closely linked with water security and success in irrigation. FAO figures show that between 30 and 40 percent of the world's food comes from the irrigated 16 percent of the total cultivated land. Around one-fifth of the total value of fish production comes from freshwater aquaculture; and current global livestock drinking-water requirements are 60 billion litters per day. Forecasts estimate an increase of 0.4 billion litters of water per year for livestock consumption.

The Second World Water Forum, (The Hague, October 2000), recognizes water as a scarce commodity. Its Vision Management Unit stated that supply and demand management has to go hand in hand for removing the mismatch between water resources and agriculture and food needs. To ensure a sustainable rural development “A holistic, systemic, participatory, innovative institutional mechanisms” is needed.

2. Surface Water Resources

Surface water resources used in agriculture and food production include water from rivers, lakes and ponds. Surface water is found in streams (rivers, creeks), or is stored in lakes and dams. Surface water systems are continuously interacting with underground and atmospheric water.

The American continent contains some of the world’s largest rivers and many countries are considered “Water rich”; such as Canada, United States of America, Brazil and other countries of Central and South America. However, regional and temporal variations make even parts of these countries suffer from droughts, while on an annual basis, only 1% of the total volume of water is withdrawn in South America. The United States has some of the highly productive surface water from rivers in California and the Pacific Northwest. In Mexico, approximately 4.2 million (68%) hectares are irrigated with surface waters, and the remaining; some 2 million hectares are served by groundwater pumping. Presently, irrigation uses about 70% of waters withdrawn from global river systems, 60% of which gets used consumptively, the rest predominantly returning to the river systems enabling its reuse downstream.

Surface waters are stored in dams to provide a steady water supply for irrigation during the whole year. Dams are hydraulic structures artificially build to store water for irrigation, hydropower generation and flood control. Current estimates suggest that some 30–40% of irrigated land worldwide now relies on dams. Under most scenarios, there is a need for increasing freshwater storage. Increasing storage through a combination of large and small dams is critical to meeting the water demands of the twenty-first century especially in the regions under monsoonal climate, predominantly in Asia.

In Sub-Humid climatic conditions “Water Harvesting” is an additional useful technique for maximizing available precipitation amounts for orchards. The micro-topography of the area close to the trees is change and compacted creating a micro catchment area for storing precipitation close to the root system. The catchment area should be enough to provide moisture to the trees to survive until the next precipitation. In the Israeli experience, an arid zone with 200 mm winter rainfall requires approximately 40 m^2 of catchment area for each tree (WASAD, 1998). For the windbreaks in Niger and Nigeria, the basin area for each tree was set at 8 m^2. The technology involved in applying rainwater harvesting in the field is not complicated and can be adapted to the local environmental conditions of arid zones.

Surface water commonly is hydraulically connected to ground water, but the interactions are difficult to observe and measure and commonly have been ignored in water-management considerations and policies. As global concerns over water resources and the environment increase, the importance of considering ground water and surface water as a single resource has become increasingly evident. Issues related to water supply, water quality, and degradation of aquatic environments are increasingly important. The interaction of ground water and surface water has been shown to be a significant concern in many of these issues. For example, contaminated aquifers that discharge to streams can result in long-term contamination of surface water; conversely, streams can be a major source of contamination to aquifers.

3. Underground Water Resources

Underground water resources for agriculture and food production are contained in aquifers. An aquifer is a geological formation containing water in the pores and voids of the porous rock or coarse soil materials within which water is collected. Water in aquifers could be confined or it flows at relative slow rate (as compare to runoff). Moisture from precipitation that infiltrates into the soil in excess of the water holding capacity of the soils, percolates into the saturated zone and is potentially usable for aquifer recharge. Groundwater is a good source of water for agriculture at alluvial valleys and flodd plains where the water table is generally shallow. In the People's Republic of China official government reported 84,905 reservoirs with a total capacity of 457.1 Billion Cubic meters “BCM”. Out of these reservoirs, 394 are large-sized reservoirs with storage of 72.4 BCM and 81893 are small sized reservoirs with storage of 58.6 billion cubic meters (BCM).

Lifting underground waters for irrigation requires pumping, therefore is a more expensive water source than surface water. Aquifers are economical to use for irrigation if they are close to the surface and are of good quality. The aquifer discharge, the quality of the waters and pumping cost can be determined accurately by hydro-geological exploration. On the other hand, a major advantage of storing water in underground aquifers is that it can be stored for years, with little or no evaporation loss, to be used in drought years as a supplementary source of water supply. It also has the advantage that storage can be near or directly under the point of use and is immediately available, through pumping, if financing is available. Aquifers vary greatly in their nature and extent. Aquifers may be very thin or hundreds of meters thick; some are local in character, while others extend for hundreds of kilometers. As an example; the Ogallala-High Plains Aquifer in the central-western United States underlies more than 10 million ha over six states.

Figures by the U.S. Geological Survey (**USGS**,1999) estimated groundwater worldwide ranging from 7 000 000 to 330 000 000 cubic kilometers. The estimates are more than 40 times larger in one case or 40 times smaller in the other, evidencing the lack of accurate evaluations. In the United States of America the **USGS** estimates 339,000 million gallons per day (Mgal/d) of freshwater (about one quarter of the national renewable supply) was withdrawn during 1990 for use by U.S.A. homes, farms, and industries, and about 220 billion gallons per day was returned to streams after use. Areas of significant ground-water depletion in the United States include many areas in the southwestern United States: Arizona, California, New Mexico, Nevada, and Texas. The **USGS** emphasized that long-term observation-well networks are needed to provide data to monitor areas of ground-water depletion. In order to provide the information needed on large aquifers, a rotational assessment of water-level changes on these major systems should take place at least every 5 to 10 years. A Report by the Subcommittee on Water Resources, Office of Science and Technology Policy manifest that: "Assuring long-term ground-water supplies is one of the most significant natural resource issues facing the Nation today."

Groundwater is an extremely important resource for many developing countries, including Bangladesh, India, Pakistan and the entire Near East region. Dependence on ground water supplies has reached about 35% in Bangladesh, 32% in India, 30% in Pakistan, and 11% in China.

Aquifer status reports from many parts of the world manifest symptoms of management problems. Common problems include: rapid exhaustion of groundwater resources and the consequent increase in pumping costs; intrusion of poorer-quality water into the reservoir being exploited; salt water intrusion from rapid pumping near seacoasts; and mineralized deposits interacting with better-quality water. Artificial recharge of depleting groundwater storage is required where surface availability exists and where it is cost-effective. Because it deals with the complex interaction between society and the physical environment, aquifer management represents a challenge that needs an integrated approach.

4. Integrated Resources

Surface and Underground Water Resources:

Given the known interaction between surface and underground water, it is important to consider both resources in a unified way. The United States Geological Service "USGS" describes this interactions in all types of forms and landscapes. The interaction takes place in different ways:

- Streams due to inflow or outflow of ground water through the streambed.
- Perennial discharge of ground water, near the base of some mountain sides, providing good sources of water for agriculture and food production.
- Lakes interact with ground water in three basic ways. Some receive ground-water inflow throughout their entire bed; some have seepage loss to ground water throughout their entire bed; but perhaps most lakes receive ground-water inflow through part of their bed and have seepage loss to ground water through other parts.

The interaction of ground water and surface water involves physical, chemical, and biological processes that take place in a variety of geomorphic and climatic settings. Interest in the relation of ground water to surface water has increased in recent years as a result of widespread concerns related to water supply; contamination of ground water, lakes, and streams by toxic substances, acidification of surface waters; eutrophication of lakes and other changes in aquatic environments. Aquifers interrelated with flowing streams are best administered trough a water management system approach of interrelated stream and aquifer sources. In Asia, with extensive paddy rice production, effective management of water resources requires an understanding of the role of riparian zones and their dependence on the interaction of ground water and surface water.

The tendency for chemical contaminants to move between ground water and surface water is a key consideration in managing water resources. The water quality concerns will be discussed in more detailed in following sections.

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