Impact of climate change on water resources in MENA countries: An assessment of temporal changes of land cover/land use and water resources using multi-temporal MODIS and Landsat data and GIS techniques

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ABSTRACT

Water resources are crucial to food security and rural livelihood. Global climatic variation, particularly global warming and changes of precipitation patterns greatly affect the agricultural production and food security. The Middle East and North Africa (MENA) includes countries with poor economies and resources (e.g. Morocco, Yemen) as well as oil-rich economies of Gulf countries (e.g. Qatar, Kuwait, Saudi Arabia). Water resources are being increasingly scarce in the MENA countries and have great impact on the standard of living particularly in countries with poor economies. In addition to water scarcity, poor water management has also been contributing to the water issues. For example, the countries with the highest per capita water consumption (e.g. UAE) in the world are also found in the MENA countries while in some countries (Jordan, Syria) agriculture consumes more than 85% of water.

Mapping water resources, monitoring the temporal changes of land cover and land use are the main ingredients in managing water resources. There are no better technologies than GIS and remote sensing to generate this information. Geospatial technologies, particularly GIS and remote sensing can be used to identify changes, vulnerable areas and potential areas for watershed development. Satellite data are available at varying level of detail ranging from 1km to 0.6m pixel size in spatial resolution supporting studies at global, regional and local levels. Once the vulnerable watersheds are identified, high resolution satellite and GIS data can be used to develop action plans at local levels.

The purpose of this paper is to map and monitor water resources and land cover/use to identify vulnerable areas in the MENA region using two countries (Morocco and Yemen) for a comparative assessment. Both Morocco (North African country) and Yemen (Middle-East country) are poor countries and characterize water scarcity, poor water management, desertification and growing food security issues.

The objectives are to

- Map water resources and catchments
- Map land use and land cover in the region
- Identify and map areas of potential hotspots or vulnerable areas

The methods include developing a data base including satellite imagery and GIS data (e.g. elevation, climate, socio-economic data), use image processing techniques to extract land cover, land use and catchment information, and use GIS techniques to analyse data and modelling vulnerability. The outcome of the paper are useful in understanding the current status of water resources, production of an inventory of resources, understanding the potential areas of water resources as well as identifying vulnerable areas in selected countries.

MENA countries

The global population is expected to increase to 9.1 billion in 2050. The major challenge is to ensure water and food availability to growing population considering increasing impact of environmental issues such as climate change, pollution, mismanagement and over use of natural resources. There is no secret about global warming, extreme climatic conditions, sea level rise and ocean acidification, however, there is a great uncertainty about the potential impact of climate change on ecosystems. It can be assumed undoubtedly that agro-ecosystems, where many developing countries depend on will have major impacts due to their close interactions with land, climate and water. The effective management of these ecosystems, particularly water and land is essential for sustainable use of resources.

Many of the middle east and North African (MENA) countries share common environmental condition and un-sustainable use of natural resources while there is a greater economic disparity between oil producing Gulf countries and non-oil producing countries.

Water issues and food security

Impact of climate variability, floods, drought and extreme weather conditions create development challenges to particularly to the countries with harsh environmental conditions or to developing countries (IPCC, 2001). Agricultural systems that depend on rain fed agriculture are severely affected by climate change impacts (Acheampong et al., 2014).

The Middle East and North Africa (MENA) region is economically highly diverse. It includes oil rich Gulf countries (e.g. Qatar, Saudi Arabia, Kuwait) and resource scarce poor countries such as Yemen, Morocco, and Malta. In average, the MENA region is the most water scarce region of the world. Water issues are directly related to prolong droughts in the region. Agricultural and hydrological droughts directly affect the millions in the region as the livelihood of people primarily depends water Wilhite and Glantz, 1985; Cui et al., 2015).

Worldwide, the average water availability per person is close to 7,000 m3/person/year, whereas in the MENA region, only around 1,200 m3/person/year is available. One half of MENA's population lives under conditions of water stress. Moreover, with the population expected to grow from around 300 million today to around 500 million in 2025, per capita availability is expected to halve by 2050.

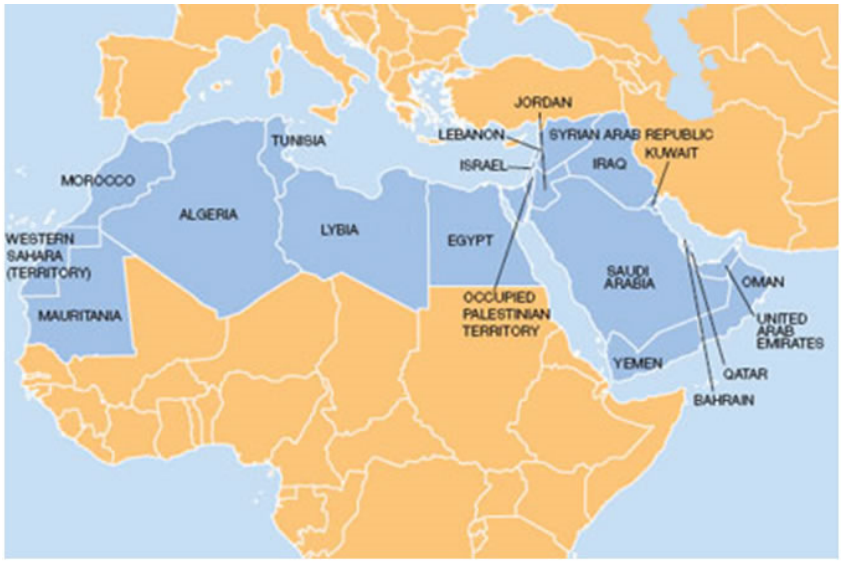
According to the World Bank (2008) findings, about half of the countries in the region consume more water than they receive while 85% of the water in the region is used for irrigation. The World Bank study reported that the per capita water availability in MENA is

projected to fall by half by 2050. The alarming situation is that these predictions can be worsening if potential climate variability is taken into account. Global projections of climate change indicate a drop in rainfall of 20 to 30% and increase temperature accelerates evaporation creating severe drought conditions. This is further supported by the studies based on satellite derived rainfall data which revealed a recent drying trend in Central Equatorial Africa (Diem et al., 2014). The key issues related to water in the region include unsustainable and inefficient use, ineffective policies, deteriorating water quality and excessive dependence on government water supply (World Bank, 2010).

The main impact of the water scarcity is in the food production. The trend will have impact on agricultural systems where majority of people depend on subsistent agriculture. Further, the population in the region is expected to increase from 300 million today to about 500 million by 2025 however, current per capita water availability of 1200 m3/person/year is expected to decrease by half by 2050.

The source of water in the region varies from country to country. Some, like Egypt and Iraq rely mostly on surface water from large international rivers. Others, like Yemen, Djibouti and the Arab States of the Gulf Cooperation Council countries depend almost entirely on groundwater and desalination, while others use a mixture of surface and groundwater. Most countries have mobilized almost all available surface water, and many major rivers do not reach the ocean.

More than in any other region, water in MENA is a development issue. Water is a driver for several ecosystem functions, including biomass and crop yield as well as supplying and regulatory ecosystem services. It is also principal input in enhancing food production and irrigation. Rainfed agriculture is the dominant activity in many of the MENA countries.



Continuous supply of water and proper use of water support food production mainly in rural areas where about three-quarters of poor people live (World Bank, 2009). For sustainable food supply, development of regional agricultural production is at the forefront of achieving food security.

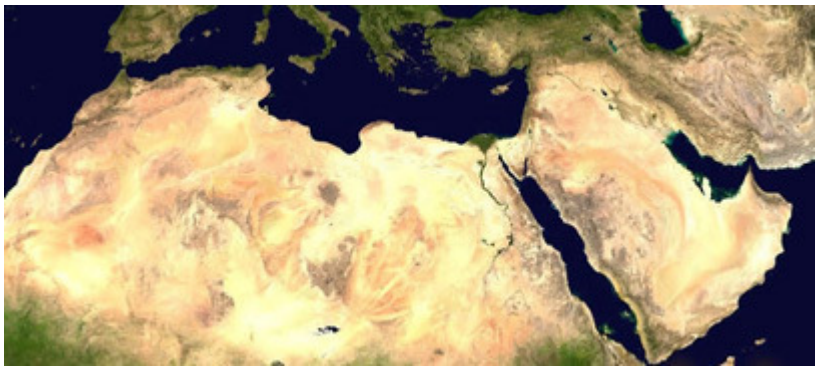
Food security cannot be achieved without water security. Currently, region imports more than 50% of its food some countries (e.g. Yemen, Djibouti, Comoros) in the Mena region and are vulnerability to price fluctuations (International Food Policy Research Institute). Water availability limits agricultural potential and leads to competition between water use in

agriculture which uses up to 90% of all water. According to the report of IFPRI, the food security is threatening the livelihood of the people because of their high dependence on imports, generating foreign exchange to get foods and rising food demand driven by high population growth and limited potential for agricultural production because of water issues (2014). There is a large gap between national demands for food and the availability of domestic food sources. This trend can be seen from Iran to the Morocco in the west of the MENA region.

FAO reports that food security is an enormous challenge in MENA countries. Among the top challenges cited were high population growth, inefficient agricultural practices and reliance on imports, and exposure to such threats as climate change and regional conflict. (fao, 2014, http://www.dailynewsegypt.com/2014/02/26/food-security-enormous-challenge-mena-countries-fao/)

Currently, region imports more than 50% of its food and some countries in particular such as Yemen, Djibouti, Comoros are highly vulnerable to price fluctuations (International Food Policy Research Institute). Due to the price fluctuations in the food import sector, many countries will have food security issues indicating heavy reliance on food import is not a viable source for growing population.

For sustainable food supply in the region, it is important to develop the agricultural sector. In order to address these issues related to food security in the region, a comprehensive understanding of a number of areas is essential in planning and managing water for future food supply in the region. These include (a) assessment of current status of water resources, (b) understanding the trends of surface moisture conditions, (c) mapping current agricultural lands, and (d) identifying areas for potential water resources for agricultural developments and locating potential hotspots.



EODIS, 2014

Total land area of Qatar is 1100 ha compared to 1,256,964 ha in MENA countries. Shrublands, Savannah and grasslands constitute 26% and 70% of land are barren or sparse vegetation. The wetland and water bodies cover about 4% of the country (UNEP).

Use of spatial information technologies in addressing water issues

Watersheds are crucial to food security and rural livelihood. The management includes integrated use of vegetation and water resources to raise agricultural productivity and rural income ensuring food security. Mapping water resources, monitoring the temporal changes of watersheds or catchments and identification of potential ground water resources are the main ingredients in managing water resources. There are no other technologies than GIS and remote sensing to generate this information. Geospatial technologies, particularly GIS and remote sensing can be used to identify changes, vulnerable areas and potential areas for watershed development.

Spatial information technology tools help develop rural areas in mapping resources, infrastructure at the base level and then use modelling tools in assessing the impact of external and anthropogenic factors on the environment and people. The system uses a combination of advanced spatial information technologies (GIS, Remote Sensing, GPS) along with geostatistical tools to manage spatial data, model impact scenarios and to provide accurate information on a temporal basis. When combined, these technologies become a very powerful decision support tool necessary for planning, monitoring and policy development at low cost. It has been widely used in the production of resource inventory, vulnerability studies, predictive mapping, resource management and change analyses.

One of the advantages of spatial information systems is that it is still evolving with new frontiers. In addition to mapping, predictive modelling, this research will use two of the new frontiers: participatory GIS and multi-criteria analysis in addressing water issues and food security in MENA countries. The issues cannot be solved by potential water resource mapping, introducing new seed varieties or importing foods. Community participation in planning at village level is essential. Participatory GIS (PPGIS) developed in recent years allow application of GIS at community level with the input from farmers. In addition, their expert opinion can be incorporated into GIS for prioritizing and ranking objectives using multi-criteria analysis. The project will utilize all the benefits from recent advancements of spatial information techniques to generate information for addressing water and food security issues in the MENA and in particular Qatar region.

One of the main obstacle in finding solutions to the issues in the MENA region is lack of baseline geographic data. Here, a system will be develop to enter GIS data directly from the field using internet and cloud-base GIS server. GIS database can be updated regularly even by a non-GIS specialist. Updating map data using wireless technology would help disseminate geographical information to the farming communities and local decision makers. For example, weather information and maps acquiring from satellites help farmers plan ahead with crops and marketing.

Vulnerability to climate change is a function of exposure to a hazard (.e.g. extreme weather change such as rainfall or temperature), sensitivity to the hazard (in rural agricultural economies crop yield is highly sensitive to lack of rainfall/drought) and adaptative capacity (ability of a system or community to manage the impact (Satin, 2001, page 10).

MODIS data is acquired at a high temporal resolution, and it is expected to continue acquiring data for many more years, making its good data source for monitoring water change at the continental to global scale.

The MODIS data available at three levels of spatial resolutions (1000m, 500m and 250m) and in this research we will use 8-day 250 and 500-meter atmospheric corrected reflectance products for 12 years (2000 through 2012). These composite images will be pre-processed again to remove any cloud pixels using the MODIS cloud mask data. The 250 and 500-meter MODIS data acquired at 7 wavelength bands are suitable of extracting moisture information employing NDVI and NDWI tools for the MENA region.

Band	**Wavelength region**	**Wavelength μ**	**Equivalent Landsat Bands**
1	Red	0.62-0.67	3
2	Near Infrared (NIR)	0.841-0.876	4
3	Blue - Green	459-749	1
4	Green	545-565	2
5	NIR	1230-1250	4 & 5
6	Mid Infrared (MIR)	1628-1652	5
7	Mid Infrared (MIR)	2105-2155	7

Drought assessment can normally be carried out using MODIS vegetation index (NDVI) and vegetation water index (VWI). The NDVI has been found to be the best index for drought detection as it has better relationship with precipitation and VWI (Bajgiran, 2009).

NDVI reflects changes in chlorophyll content and vegetation amount and has proved to be useful tool for studying vegetation cover change and amount in semiarid and arid environments (Weiss et al, 2004; Fensholt and Sandholt, 2003). VWI can provide valuable information on vegetation and soil water stress and detecting drought status. When combined with normalized difference vegetation index, the indices can give reliable information on water availability, drought status, vegetation vigour and phenology (Bajgiran et al., 2009).

NDVI is particularly suitable for vegetation greenness mapping (Ceccato et al., 2002b) and some researchers have found suitable for soil moisture investigations. In addition to vegetation indices, GAO (1996) developed Normalized Difference Water Index (NDWI) which is related to vegetation water content. The index uses the ratio of reflectance in NIR and SWIR correspond to bands 2 and 7. Inclusion of additional SWIR band in MODIS compared to other sensors such as AVHRR helps researchers to assess the vegetation and soil moisture conditions at regional and global scales.

MODIS satellite data have particular advantage as it has appropriate water absorption bands for retrieving moisture content from vegetation and soil. Its high frequency temporal data allow us to study regional and global environmental changes. Modis bands 7 and 2 are particularly suitable for surface vegetation and drought conditions estimations.

Anticipated results

The project will yield deep understanding of the moisture changes over a long period with very high accuracy. The steps outlined in the research design will produce the results achieving the goal. The preliminary results will be presented at the conference.

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