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Libyan Agriculture: A Review of Past Efforts, Current Challenges and Future Prospects

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Abstract
By increasing the agricultural sector productivity, Libya will decrease their current dependency on other countries for food and potentially could stimulate the economy by increasing food exports. Like many other countries in the region, agriculture in Libya is constrained by its limited arable land and low soil fertility. Desertification and limited freshwater resources are the two greatest challenges for future agricultural development. In addition, the intrusion of the seawater into the groundwater is causing soils to become salt-affected. Many important crops in the country are susceptible to pests. These challenges have not been addressed because of the lack of specialists and institutions engaged in the National Plant Protection Program. Increasing crop productivity depends on identifying proper management strategies of natural resources and pests as well as seed development.
Keywords: agriculture, desertification, food, Libya, salt-affected soils, soil

1. A brief history of climate and geography of Libya

Libya is located in the Maghreb Region of North Africa (Fig. 1) encompassing approximately 1.6 million km^2 (Saad *et al.* 2011). It is bordered by the Mediterranean Sea to the north, Egypt to the east, Sudan to the southeast, Chad and Niger to the south, and Algeria and Tunisia to the west (Lariel 2015) (Fig.1).

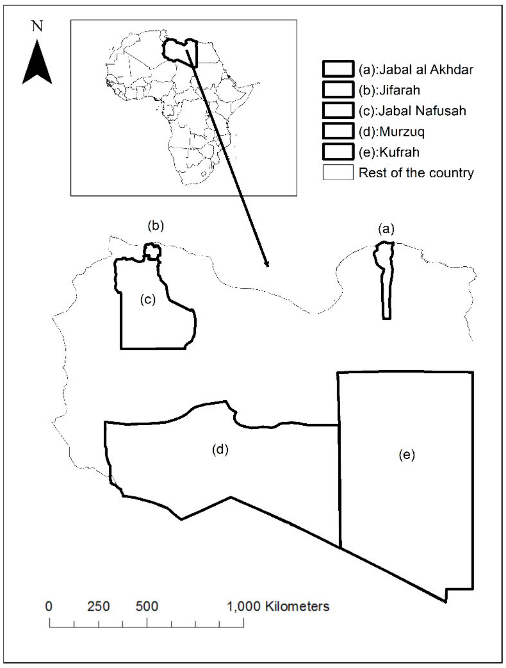

Figure 1. Location of Libya within the African continent, and major cities and the four major climatic regions within Libya. Adapted from Saad et al., 2011.

Historically, Libya was comprised of three main provinces: Tripolitania, Cyrenaica and Fezzan (Sunderland & Rosa 1976). Tripolitania is the northwestern corner of the country including the Nafusah Plateau. Cyrenaica, the largest geographic region, represents the entire eastern half of the country including the Jabal al Akhdar, and Fezzan is home to the desert lands, including the Sahara Desert (Hegazy *et al.* 2011). Geographically, Libya has traditionally been divided into four regions, each with a different climate: (1) the Coastal Plains run along the Mediterranean Sea and experience dry summers and relatively wet winters; (2) the Northern Mountains, which border the Coastal Plains, include Jabal Nafusah in the west and Jabal al Akhdar in the east. The Northern Mountains have the benefit of a plateau type climate with greater rainfall (approximately 500 mm in Jabal al Akhdar and 400 mm in the Northern Mountains, annually) and lower temperatures (approximately 20 °C); (3) the Internal Depressions, located in the center of Libya, is where pre-desert and desert climatic conditions prevail; and (4) the Southern and Western Mountain Range characterized as an area with little annual rainfall, from 50 to 150 mm (Alldrissi *et al.* 1996; Laytimi 2005) (Fig.1).

The remainder of this paper is an exhaustive review of the publications related to agriculture in Libya. In general, the cited literature documents a positive interest assisting agriculture development in the country. However, some information may already be outdated. The state of current natural resources, land under agriculture and related economics may be very different since the recent unrests in the country. It is the authors' hope that this paper assists Libya in becoming a more self-sustaining nation.

2. Water Resources

2.1 Rainfall Depending on the geographic region, the Libyan climate is characterized as either semi-arid (Coastal Plains and the Northern Mountains) or arid (Internal Depressions and Southern and Western Mountain) (Shaki & Adeloye 2006). Rainfall is limited, and its volume and distribution varies from year to year (El-Asswad 1995), occurring primarily from October to March in Jabal Nafusah in the west, and Jabal al Akhdar in the east (Saad *et al.* 2011). The amount of rainfall decreases the further inland from the Mediterranean Sea. Because of these dry conditions, agriculture is primary dependent on irrigation.

2.2 Water Availability

Water resources in the country originate from seawater desalination, wastewater, surface water, and groundwater. The existing desalination plant produced 70 million m^3 in 2012, exclusively for municipal and industrial purposes (AGUASAT 2016). The present capacity of wastewater treatment is estimated at 74 million m^3 per year, with treated effluent primary targeted towards agricultural purposes. Surface water, originating mainly from rainfall, represents approximately 170 million m^3 per year, contributing less than 3% of the total water use (Aqeil *et al.* 2011). Sixteen dams and several reservoirs have been constructed to manage surface water resources (Salem 2007; Wheida & Verhoeven 2004).

Groundwater, both shallow and fossil aquifers, represent the main source of water supply in the country (Salem 2007). Both shallow (Jabal Nafusah, Jifarah, Jabal al Akhdar, and Murzuq) and fossil groundwater (Kufrah) (Fig. 2) are recharged by rainfall at a rate of approximately 650 million m^3 per year (Salem 2007).

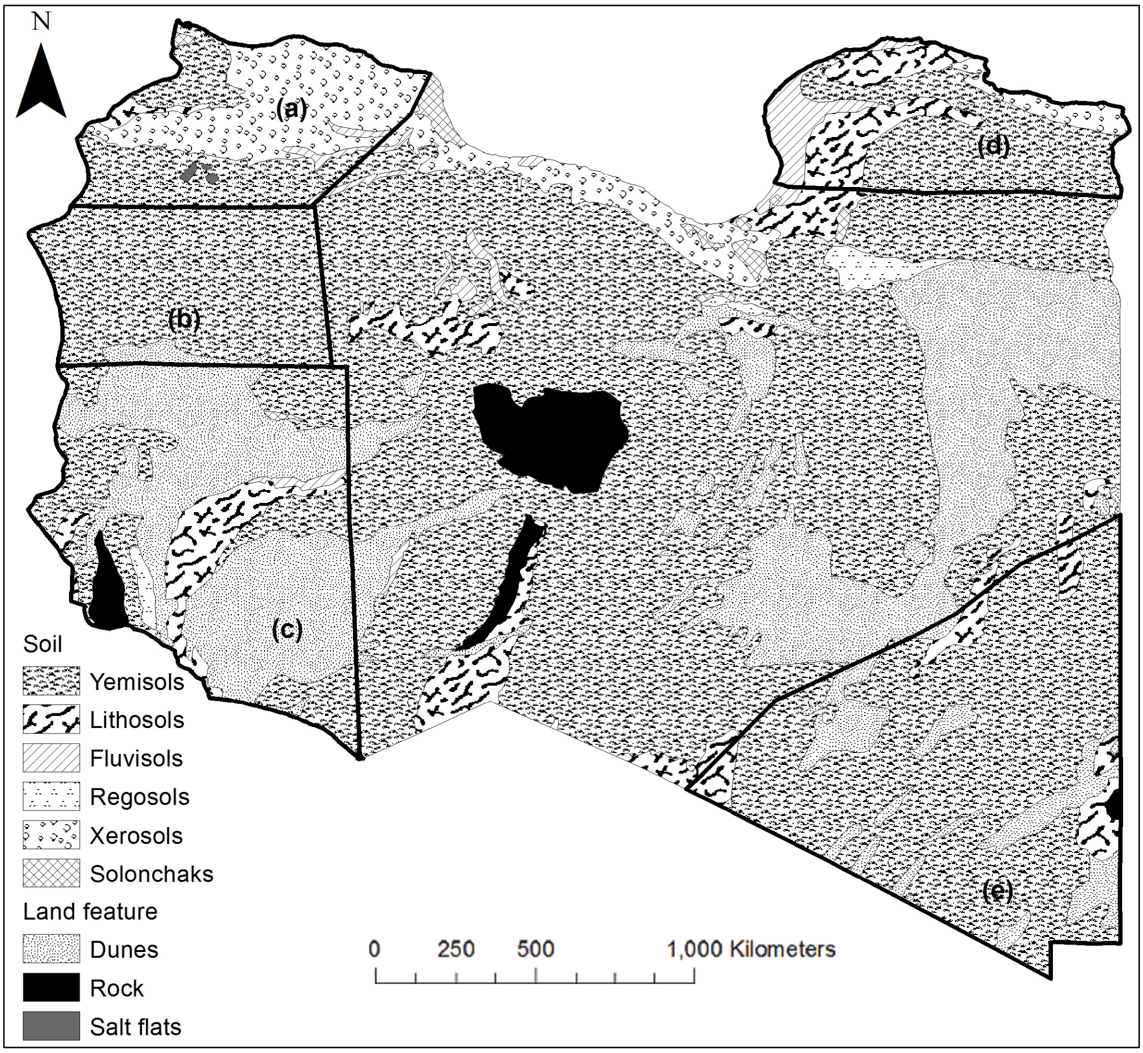

Figure 2. Soil classification and land features, and the major groundwater basins (a: Jifarah, b: Jabal Nafusah, c: Murzuq, d: Jabal al Akhdar, and e: Kufrah) in Libya. Adapted from Wheida and Verhoeven (2006) and FAO (2005).

In comparison, 2,400 million m^3 per year is withdrawn, thus exceeding the annual replenishment by approximately four times (Aqeil *et al.* 2011). The decline in water level and resulting seawater intrusion make the remaining groundwater resources almost unusable because of their high salinity. From 1950 to 1990, the seawater interface advanced 1- 2 km inland, with salinity increasing significantly from 150 ppm to approximately 1,000 ppm in the coastal aquifers (El-Asswad 1995). For example, fifteen years ago, the seawater intrusion within the Kufrah basin had resulted in groundwater having a salt content of 400 -1,000 ppm (Mcloughlin 1991). It is expected that the seawater intrusion is still increasing. The characteristics of the main aquifers in Libya are summarized in Table 1.

To make the country self-sufficient in food production, the Libyan Water Authority implemented the Great Man Made River Project (GMMRP) (Wheida & Verhoeven 2007). The GMMRP, begun in the 1980's and was transferring 7.1 million m^3 of water per day from the Kufrah and Sarir aquifers to the coastal areas through a system of pipes traversing 4,500 km. The GMMRP offered water for irrigation and other uses to approximately 87,981.8 km^2 from the Internal Depressions region to Benghazi on the coast (Aqeil *et al.* 2011). The water pumping stations are no longer operating because major parts of the GMMRP have been damaged during the recent unrest in the country.

Table 1. The characteristics of the shallow and fossil basins in Libya

Basins	Area (Km^2)	Total dissolved salts (mg/l)	Present and probable pollution Sources	Effect of exploitation
Jabal al[a] Akhdar	145,000	1,000–5,000	Sea water intrusion and waste disposal	Water level decline and sea water intrusion
Kufrah[b]	760,000	200–2000	Humans and fertilizers	Water level decline and local contaminations
Jifarah[a]	20000	500 – 4500	Sea water intrusion, fertilizers and waste disposal	Water level decline and sea water intrusion
Jabal Nafusah[a]	215,000	1,000–5,000	No pollution	Water level decline
Murzuq[a]	350,000	500–1,500	Humans and fertilizers	Water level decline and local contaminations

Source: Adopted from Wheida and Verhoeven, 2006.
[a] Shallow basin.
[b] Fossil basin.

3. Libyan Soils

Generally, the soils in Libya are very shallow and coarse, thus they are low in organic matter content and water holding capacity (Laytimi 2005). Soil studies have been conducted by the Russian and American governments over the last four decades, using various classification systems and methods of soil analysis (Newr 2006). The Food and Agriculture Organization (FAO) generated a Libyan soils map using their own classification system based on both previously mentioned surveys (Fig.2). Soil orders include Yermosols, Lithosols, Xerosols, Fluvisols, Regosols, and Solonchaks covering 62.745%, 6.78%, 5.02%, 1.38%, 0.63%, 0.52%, respectively of the country's area. The majority of these soils are silty loam in texture (63 %), followed by loamy very fine sand (7 %), coarse loamy (5 %), loamy (1 %), sand (0.6 %) and sandy clay (0.5 %) (Abagandura *et al.* 201X). The remaining 22.9% of Libya's land mass is covered by salt flats, rock and dunes (Abagandura *et al.* 201X).

Approximately 53.5 % of all Libyan soils are estimated to be degraded (Abagandura *et al.* 201X) to varying degrees, losing their quality and productivity primarily due to salinization, water erosion, and wind erosion. Ben-Mahmoud et al. (2000) documented that approximately 1,900 km^2 is affected by salinity, probably due to using seawater for irrigation, poor drainage, and increasing concentrations of salts in the irrigated water from seawater intrusion. Salinization is also the primary type of soil degradation (46.4 %), with water erosion and wind erosion causing 6.4 % and 0.66 % of soil degradation, respectively (Abagandura *et al.* 201X).

4. Crop Agriculture

Libya has several water and soil issues not conducive to agriculture, with approximately 34,700 km^2, (slightly over 2 % of the total area of the country and 50 % of the arable land) being farmed each year (Secretariat of Economy Planning, Libya, 1993). Approximately 95 % of total land area in the country is desert, while 4 % is grassland, suitable for grazing animals, and 1 % is forest (FAO 2012).

The most important agricultural zones include Jabal al Akhdar and Jabal Nafusah, Jifara plain, Kufrah and the desert mountains to the south (Environment General Authority (EGA) 2008). Croplands cover 355,000 ha, pasture and rangeland comprise approximately 13,300,000 ha, and forestlands encompass about 547,000 ha (Alldrissi *et al.* 1996). Approximately half of all crops are grown in Jabal al Akhdar with the other half grown in Jabal Nafusah, Kufrah and the desert mountains to the south (EGA 2008).

There are 163,714 Libyan farms (FAO 2005), with 90 % being less than 20 ha, 9 % between 20-100 ha, and 1% greater than 100 ha (Lariel 2015). Farms greater than 100 ha are mostly owned by the government (Laytimi 2005). Due to the arid conditions in the country, irrigation is becoming a common practice to supply water to crops. Approximately 470,000 ha are equipped for irrigation (FAO 2005), and are mainly irrigated from groundwater (Laytimi 2005). The use of greenhouses for agriculture is increasing with 1000 ha in use in 1991 (Jensen and Alan, 1995) to 2500 ha in 2009 (Leonardi & De Pascale 2009). No information is available about the greenhouse cultivation, but from the main author's experience in Libya, greenhouse operations are both government and privately owned, with the majority of them in Jabal al Akhdar to grow vegetable crops such as tomatoes, cucumbers and potatoes. Hydroponics is also utilized.

Libya's cereal production is limited to wheat and barley, and the main non-grain agricultural crops include potatoes, onions, tomatoes, watermelons, oranges, dates, and olives (United States Department of Agriculture 2014). Production of the main crops in 2012 are shown in Figure 3 (FAOSTAT 2012).

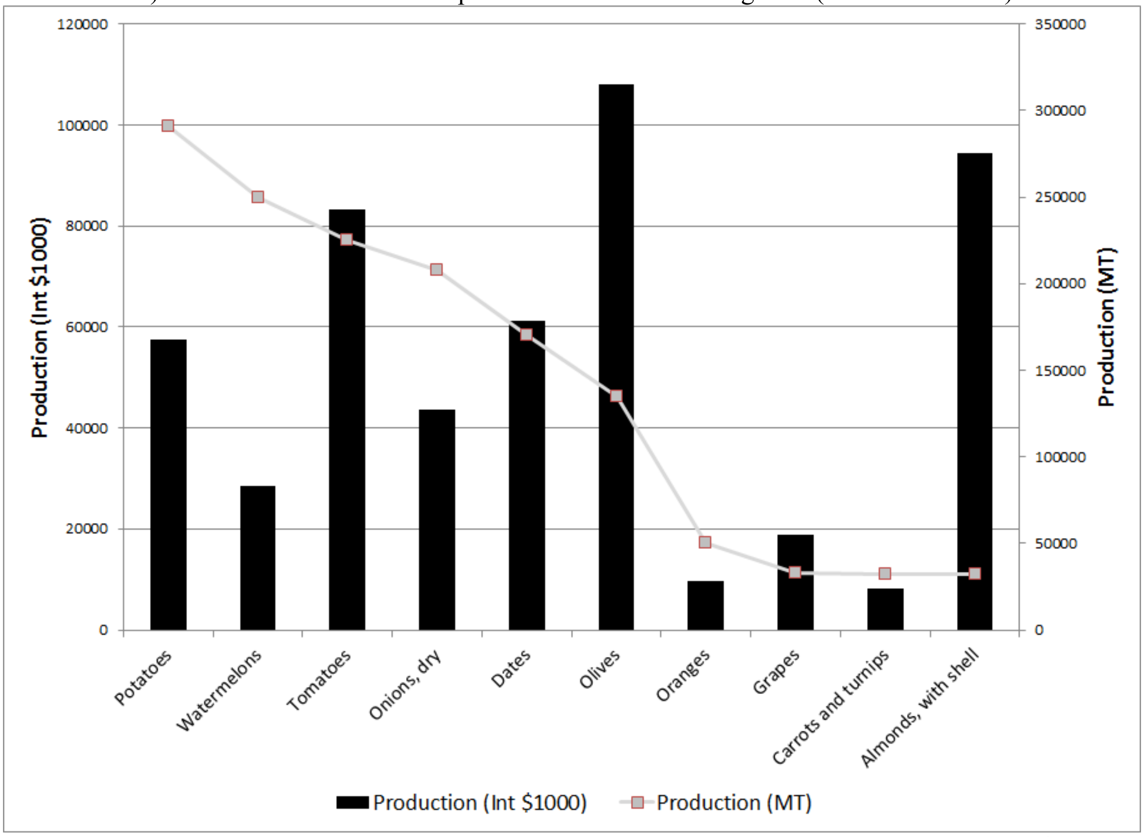

Figure 3. The main crops produced in Libya in metric tons with the international prices in $1000 USD. Source: FAOSTAT, 2012.

Due to the recent unrest in the country, the 2015 cereal crop was almost 10 % below average (254 000 tonnes). As a result, Libya imported up to 90 % cereal for its consumption requirements in 2015. Currently the country depends significantly on imported foodstuffs. Imports in 2015 were estimated to be 3.7 million tonnes, an increase of about 7 % compared to the previous year (FAO 2016).

4.1 Seed Sources

Historically, agricultural seeds in Libya are sourced primarily from a farmer's crops (Alidrissi 1996). In 1975, the Libyan–Romanian Company for seeds and seedlings was established to promote agriculture in both countries. This company continued until 1991 (FAO 2006). In 2005, the Elkhams Center was established to facilitate seed production for cereal crops and vegetables and the amount of seed that the Center produced and distributes annually is unknown. Similar to other factories, the Center was destroyed during recent unrest in the country. On an annual basis, Libya imports 20 tons of both wheat and barley, 8 tons of forages, 346 tons of legumes, and 150 tons of vegetable seeds (Laytimi 2005). Because of the uprising in the county, seeds have become scarce and expensive. As a result, the Food and Agriculture Organization of the United Nations (FAO) has provided vegetable seeds to farmers throughout the country (FAO 2012).

4.2 Pests Affecting Significant Agronomic Crops

The primary pests affecting Libyan agriculture (insects, nematodes, fungus, viruses, snails and slugs) are discussed below. Although important plants in the country are susceptible to being infected by these pests

(Edongali & Dabaj 1982), the number of Libyan specialists and institutions engaged in the National Plant Protection Program is not sufficient to address these issues.

4.2.1 Insects

Lal and Naji, who documented scale insects as one of the most problematic pests occurring in many regions of Libya, conducted the earliest published pest survey in 1979. Scale poses a threat to cereal, vegetable, ornamental, fruit and forest tree crops. Since 1980, entomologists have recorded additional harmful insects found in Libya. For example, Mohamed *et al.* (1994) identified that the cotton leafworm *Spodoptera littoralis* pest insect in an alfalfa project in Benghazi. In 1999, the chafer insect was reported for the first time in the southwest region of Libya as destroying the leaves and flowers of alfalfa fields and other crops such as sesame and Jew's mallow, and attacking the new leaves of peach (Dodo *et al.* 2003). At the same time, Maghrabi and Mahfuod (2003) recorded red flour beetle destroying wheat.

Since 2002, the use of insecticides to protect vegetable crops grown in greenhouses (particularly in Benghazi) has increased in an effort to control insect pests and improve vegetable quality and yield (Elbagermi & Alaib 2002). Limited availability of insecticides has resulted in the following insecticides being mainly used: actellic (2-diethylamino-6-methyl-4-pyrimidinyl-0-dimethylphosphorothioate), and malathion (0,0-dimethyl phosphorodithioate of diethyl mercapto-succinate (56)) (Omar 2013 pers. comm.). Using theses pesticides can contaminate soil, water, air and other vegetation, and may decline the populations of beneficial soil microorganisms (Aktar et al. 2009). The two aforementioned insecticides are broad spectrum and may pose more harm than good. For example, the same authors reported that malathion insecticide was detected in the air after application to the soil. In addition, the use of the same pesticides for long time may lead to resistance among the target pests (Bourguet *et al.* 2000).

4.2.2 Nematodes

Nematodes are recognized as one of the main threats to various agricultural crops but has especially been documented to be a major pest to tomatoes, potatoes and cucumbers (Edongali & El-Majberi 1988). Root-knot (species not disclosed), root-lesion (species not disclosed) and citrus nematodes (species not disclosed) are common among all the cultivated crops in the country, causing damage to their respective host plants (Ehwaeti 2003). The cucumber root-knot nematode (*Meloidogyne spp*.) is found throughout the country and the most destructive (Fourgani & Edongali 1989). The four species of root-lesion nematode attack herbaceous and woody plants, being especially problematic for date palms. The citrus nematode has been found in the Coastal Plains and Internal Depression regions country (Edongali & El-Majberi 1988). Other plant-parasitic nematodes are known to infect various crops. For example, *Xiphinema indexis* is problematic in grapes and fig orchards (Adam & Amer 2014). A survey conducted by Edongali and Dabaj *(1982*) found *Heterodera crucifera* presence and damage on cabbage, cauliflower, and other cruciferous plants in Tripolitania. Siddiqi *et al.* (1987) documented a new species of *Telotylenchus siddiqi* infecting and causing damage on peach trees in the same region.

Various ways to control nematodes are used in Libya, with chemical treatment being the most common (Ehwaeti 2003). However, these chemicals are extremely toxic to humans and other non-target organisms, and therefore they were abandoned internationally (FAO 1987). Currently, Temik and Vyadate (chemistry not disclosed) as well as other indigenous nematicides are most commonly used in agricultural fields (Ehwaeti 2003). In addition to synthetic nematicides, cultural practices, organic amendments, and plant extracts have also proven to be effective in nematode control. Moreover, several fungal isolates are also used to inhibit the hatching of root-knot nematode eggs (Ghazala *et al.* 2003).

4.2.3 Viruses

While crop-damaging viruses infect many plants in the country, it is unlikely that all have been recorded (Zidan *et al.* 2002). Several studies have documented viruses infecting broad bean, citrus, and ornamental plants such as pittosporum. Several broad bean viruses in the western region of Libya have been identified, including the bean yellow mosaic virus, faba bean necrotic yellow virus (Fadel *et al.* 2003; Zidan *et al.* 2002), the pea seed borne mosaic virus, and alfalfa mosaic virus (Fadel *et al.* 2003). Viruses is one of the main problems affecting citrus production in Libya (Joseph 1995). Citrus orchards have been infected by Citrus tristeza virus for almost 35 years (Abukraa 2009).

Limited information is available on how producers are controlling viruses. According to Abukraa (2009), the use of cachexia-free budwood is the recommended method for preventing the introduction of citrus tristeza virus into orchards. No other information on virus control strategies was found.

4.2.4 Fungus

A number of studies have reported several plant diseases caused by fungus including powdery mildew (Khan & Faraj 1982), leaf spot (Farag *et al.* 1982), leaf blight (El-Maleh 2003), inflorescence rot (Alwani & El-Ammari (2000), and rust (Mohamed 1975). In 2002, Czembor reported symptoms of powdery mildew (*Blumeria graminis f.sp.*) on barley. Leaf spot was observed on fig tree leaves in Tripolitania (Farag *et al.* 1982). Maize is highly susceptible to the leaf blight disease caused by *Cochliobolus heterostrophus* (El-Maleh 2003). El-Alwani and El-Ammari (2000) reported leaf spot and leaf blight diseases on date palms in various regions of Libya, and documented a serious disease of the date palm caused by *Mauginiella scaettae.* Rust diseases attack a number of plants in the country. The stem rust fungus *Puccinia graminis* is damaging to wheat and barley (Mohamed 1975). Limited information exists on fungicides used to control diseases in Libya, however, Baraka *et al.* (2003) reported Galben, Previcur–N, Sandofan, and Ridomil MZ (chemistry not disclosed) are used.

4.2.5 Slugs and Snails

Slugs and snails are the only two animal pests known to Libyan agriculture. The northeast region of Libya is inhabited by four species of plant damaging terrestrial slugs (*Tandonia rustica*, *Tandonia sowerbii*, *Milax gagates*, and *Malacolimax tenellus*) (Nair *et al.* 1996). Slugicides are commonly used to control this pest (Omar, 2015 *pers. comm.*). The land snails Helix aspersa and Helix pomatia were reported for the first time in 1991, attacking and causing extensive injury to ornamental plants in Benghazi (Kamel *et al.* 1992). Bisheya *et al.* (2003) documented that snails are also found along the coastal area from Misurata to Elkhams in the eastern part of the country with white snails (*Theba pisna*) being the most common one.

4.3 Chemicals used on Crops

Because of the population growth over the last century, pesticides and fertilizers play an important role in increasing land productivity in Libya.

4.3.1 Crop Pesticides

Libya imports a variety of pesticides including disinfectants, fungicides, and insecticides. There is public concern about their extensive use because of their potential harmful effects on humans, animals, and the environment (Laytimi 2005). Soil pollution resulting from heavy pesticide usage has been documented in some areas of Jabel al Alkder (El-Barasi *et al.* 2010). Many countries, including Libya, have taken special measure to control the entry and the use of these substances. According to Elfallah and Boargob (2005), the control of pesticides has improved in recent years due to the collaboration between the Customs Authority and the EGA with regard to importation and local use. To reduce risks from such chemicals, soil solarization has been implemented in the western region of Libya as a means of pest control for crops under greenhouse production (Dabaj 2003).

4.3.2 Crop Fertilizers

Between 1995– 2002, the average annual total fertilizer use was 67,500 tons per year, or an average of 32 Kg per hectare of arable land (Laytimi 2005). This amount fluctuated yearly due to climatic conditions, the amount of fallow land, and the country's reaction to United Nations sanctions (Laytimi 2005). Phosphate fertilizer is the most common fertilizer applied, making up approximately 55% of all fertilizers applied. Nitrogenous fertilizers, (primarily urea), is the second most commonly applied fertilizer followed by potash fertilizer (Laytimi 2005). The establishment of the Libyan Fertilizer Company in 2009 introduced Libya to the global fertilizer industry and market, opening the way for production growth and market expansion. Currently there is one factory located in approximately 700 km west of Tripoli, with a combined daily production capacity of 2,200 tons of liquid ammonia and 2,750 tons of prilled urea (Hovland 2013), however, it is currently not operating due to recent unrest in the country.

5. Overcoming Current Challenges

Agriculture in the country is primarily dependent on underground aquifers for its irrigation needs (Alghariani 2002). Since groundwater withdrawal exceeds natural aquifer replenishment, Libya initiated a cooperation program with neighboring countries aimed at the adoption of a long-term strategy for managing shared water resources (Salem 2007). This includes exchange of information related to the present and future withdrawals, along with water level and water quality monitoring data, and species selection. For example, by identifying crops that require less water, the country was able to reduce the irrigation demand (El-Asswad 1995).

Libya is facing serious problems of soil degradation (Abagandura *et al.* 201X). Human activities including grazing and pastoral over-use has caused a significant soil desertification (Gebril & Saeid 2012). One of the reasons causing desertification in Libya is low vegetation cover resulting from warming of air temperatures and decreases in precipitation (Saad *et al.* 2011). In the past, several measures were taken to address soil erosion including, storm water capture and retention on sloping agricultural land, establishing windbreaks, and the use of crop rotations (Saad & Shariff 2011). Other on-farm strategies to increase soil health need to be investigated.

To date, few studies exist on monitoring desertification in Libya using Remote Sensing and Geographic Information System (GIS) (El-Tantawi 2005; Oune 2006; Saad *et al.* 2011). It is expected that use of GIS technology will enhance the country's ability to identify occurrence and type of soil degradation issues (Abagandura *et al.* 201X), and thus begin to make informed decisions on where to focus efforts and what types of management strategies will be needed to increase agricultural productivity.

In addition to the water and soil challenges, Libya's dry climate provides favorable conditions for plant pests. Public and government awareness of the danger of serious pests in agriculture is limited.

6. The Future of Libyan Agriculture

The repercussions of soil and water issues (such as irrigation with high salinity) on agricultural development and food security may not be fully understood by many. Libya is seeking solutions for limited water resources by implementing modern, high-efficiency irrigation systems. Drip irrigation similar to those found in Egypt (El-Habbasha *et al.* 2015), Turkey (Acar *et al.* 2014), Tunisia (Thabet 2013), and Syria (Hussein *et al.* 2011) is being promoted to allow for deficit irrigation and conservation of water sources.

Another way to face the increasing demand for water may be by using soil surfactants which can enhance the properties of soil that increase its water-holding capacity, thereby reducing agricultural water demand (Cisar *et al.* 2000). For example, the addition of a wetting agent to a sand soil in Egypt improved its physical properties and barley plant growth (Mohamed & Magdi, 2005).

Soil degradation is an important issue in the country because of its adverse impact on crop yields. Incorporating residue or retaining them on the soil surface in Libya can be an important management to prevent soil degradation by wind and water erosion (Turmel *et al.* 2015). Ruiz-Colmenero *et al* (2013) reported that using cover crops prevented from soil erosion in Spain (Mediterranean country) which has a semiarid climate similar to Libya.

Although a few number of African farmers including Libya use remote sensing information (Lowenberg-DeBoer & Erickson 2010), the adoption of precision agriculture (knowledge-based technical management system) can be another future soil and crop management tool in Libya (Bora *et al.* 2012; Geipel *et al.* 2015). For example, It is estimated that the United States could save 2000 tons of insecticide and approximately 1893 m^3 of herbicide if 10 % of its farmers adopts precision farming when they plant their seeds (Natural Resource Conservation Service of the United States Department of Agriculture 2006).

Recent activities showed a renewed a number of research projects promoting agricultural development in the country. In 2012, an agreement between Libyan Government and International Center for Agricultural Research in the Dry Areas (ICARDA) was established to identify several priorities for the future in Libya, particularly on irrigation management and cereals production (ICARDA 2012), but has since been postponed. Libya was also provided 71 million dollars in funding from the FAO in 2012 to develop different important areas for agronomic advancement, such as plant production, pesticide management, seed development, and natural resource management to increase food production (Libya Herald 2012). Due to unsafe circumstances in the country (Combaz 2014) (mainly in Tripoli and Benghazi), these FAO programs have been minimized and are managed primarily from regional offices in Egypt and Tunisia (Omar 2015 *pers. comm.*)

While these efforts will have a direct effect on governmental operated farms, a strong outreach program will be needed to assist smaller private and family farms.

7. Conclusion

This paper was commissioned to examine Libya's agricultural history, current challenges and the current and potential solutions. The prominent challenges in Libya include soil degradation and the scarcity of quality irrigation water sources. Secondary challenges are availability to seed sources that are salt and drought tolerant, options for plant chemicals (fertilizers and pesticides), and lack of agricultural development policies and outreach. Cooperation with international organizations to address these challenges has occurred, but has been ineffective since 2011. This has resulted in minimal advancement and the country's agricultural sector (Lariel 2015). Urgent actions are needed to address theses challenges in the future.

8. Acknowledgments

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