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Sustainable food production in marginal lands —Case of GDLA member countries

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Abstract

Sustainable food production in the changing climate and dwindling water resources in the Global Dry Land Alliance (GDLA) member countries is a real challenge, especially when considering marginal lands in dryland systems. The definition of marginal land is very vague and defined from different perspectives (*pragmatism about marginal lands*). Dryland itself indicates "*marginality*" due to water stress. In general, the abandoned agriculture land where food production is not economical, and has low inherent productivity potential is considered marginal; however, a land may be marginal for agriculture but vital for grazing. In this paper attempts have been made to give review of literature (water stress, extent of marginal saline lands, marginality). Policy matters (development of soil, water and agriculture strategies) that GDLA and member countries should consider for future sustainable food production in their countries, including but not limited to, assessment of land resources for agriculture potential, defining, mapping and characterizing marginal lands, and use of innovative technologies (conservation agriculture, climate smart agriculture, integrated soil reclamation program and capacity building) for food production, are discussed. The international perception (FAO, UNEP, CGIAR) on marginal lands is also described. An innovative approach of using national biocapacity and ecological footprint is used to assess marginality of GDLA member countries. Ecological overshoot (using 1.5 earth planets) and biocapacity debtor and creditor countries are highlighted. Challenges and best management practices for food production in marginal lands are included. Other important issues, like leasing land abroad, GDLA strategic food reserves and best management practices, innovative ideas for food production are shared. Finally recommendations are drafted for actions by GDLA, its member countries and the partners.

Key Words: GDLA, Sustainable food production, Marginal lands, Climate smart agriculture, Integrated soil reclamation program

1 Introduction

At the Millennium Development Goals (MDG) summit at the UN headquarters in New York, in a side event, the Qatar National Food Security Program hosted "The Global Dry Land Alliance (GDLA)"—Partnering for Food Security aimed at strengthening cooperation among dry land nations. The event provided a much needed forum to discuss challenges specific to dry lands which account for 45 percent of the world land area. The first GDLA workshop (November 2012) was attended by 17 countries, *GCC* countries (Bahrain, Kingdom of Saudi Arabia, Kuwait, Oman, Qatar, UAE), *Africa and Middle East* (Algeria, Egypt, Iraq, Jordan, Libya, Morocco, Namibia, South Africa, Tunisia), *Others* (Kazakhstan, Mexico). These 17 countries we are considering as GDLA member countries at time of this publication.

The word drylands "*water stress lands*" is pragmatic and perceived differently in different school of thoughts, and hence, it is continued to be debated at different levels. However, there is common consensus, about the vulnerability of drylands to desertification and marginality. Drylands ecosystem cover over 40% of the earth's land sur-

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face(Fig. 1) in all continents, but most extensive in Africa ($13 \times 10^6 km^2$) and Asia ($11 \times 10^6 km^2$) (White et al., 2002). Similarly, there is high prevalence of undernourished peoples in sub-Sahara Africa (SSA) and South Asia, where agriculture is by far the primary profession of those residing in the drylands. Dryland ecosystems face extreme rainfall variability, unpredictable droughts, high temperatures, poor inherent fertility soils (low organic matter and clay contents), soil salinization and water scarcity, and this presents significant limitations/constraints for intensive agriculture, which gives drylands their special features. Regardless of these constraints, agriculture sector has contributed significantly to the Gross Domestic Product (GDP) and economies of some countries. Even these countries are constrained by limited water and arable soil resources, optimization of these resources is often a matter of survival for dryland rural economies (FAO, 1999). The developments in the dryland region reflect the pervasiveness of poverty, which is demonstrated by the growing constraints of water, land degradation, continuing concerns about malnutrition, migration due to frequent droughts, lack of infrastructure, poor dissemination of improved technologies, and effects of government policies and further economic liberalization on the competitiveness of dryland crops (Bantilan et al., 2006). Projections indicate that Middle Eastern localities will be exceedingly vulnerable to aggregate impacts and risk of large scale discontinuities, which will exacerbate the current situation of the already progressively degraded land and is likely to intensify the already severe water stress (Met Office, 2009; Evans, 2009; Ayhan and Al-Othman, 2009; Williams et al., 2007; Burke et al., 2006). Drylands are particularly sensitive to land degradation, with 10% – 20% of drylands already degraded (MEA, 2005). The preliminary diagnostics will set the scene as how to manage the marginal lands to assure their use improves farmers well being and conserve the environment.

According to Chambers 20^{th} Century Dictionary (Kirkpatrick, 1983), the marginal land is defined as "*less fertile land which will be brought under cultivation only if economic conditions justify it*". The term "*marginal land*" has been used quite loosely without a concrete definition. The difficulty in formulating a clear definition stems from the fact that "*productivity*" varies according to the type of land use. As an instance, a land that is "*marginal*" for crop production may be well suited for grazing. "*Fragile*" land may be sensitive to degradation under cultivation but may be sustainably used for forestry. *In many dryland countries, the extent and characteristics of these lands have not been systematically assessed, nor has their suitability for biofuels or food crop production evaluated.*

Marginal lands include areas with limited rainfall, extreme temperatures, low quality soil, steep terrain, shallow (depth < 50cm), imperfectly drained, poor fertility, coarse textured, stony, heavy cracking clays, salt-affected, water logged, marshy lands, barren rocky soils, or other problems for agriculture are generally considered marginal lands. This means that once the land is declared marginal, it indicates that the land do not have sufficient capacity, for example food production, unless significant management efforts are made to improve the land quality. On the other hand, it is realistic to state the land could be marginal for one use (agriculture) and may be vital for another use (grazing), so the definition of marginal land should be taken in a perspective manner. It is also important to understand the reasons in a specific area, due to which the land is declared as marginal, this emphasizes on the diagnostics of the constraints to address the issues through scientific means, such as soil quality assessment using standard field and laboratory procedures. In this paper a comprehensive review of different aspects of marginal lands (drylands-irrigated & rainfed) has been presented, lack of soil policies, agriculture strategies, success stories and constraints to food production in marginal lands are highlighted and recommendations are drawn for sustainable food production from marginal lands, for considerations by GDLA member countries and the partners.

2 Dryland systems

Fig. 1 shows global dryland systems (DLS), where either there is lack of water or facing water stress to various levels. DLS refer to land areas where the mean annual precipitation (P) is less than two-thirds of potential evapotranspiration (PET). The lack of water in DLS constrains the production of crops, forage, wood, and other ecosystem services. Four dryland subtypes are widely recognized based on P/PET: dry sub-humid (0.5 – 0.65), semiarid (0.2 – 0.5), arid (0.05 – 0.2) and hyper-arid (< 0.05), showing an increasing level of aridity or moisture deficit. Hyper-arid areas are considered as true deserts. Drylands have less than 8% of the world's renewable water resources; this water scarcity in addition to other factors, are the main limitation in sustainable food production in DLS marginal lands.

The global DLS (*hyper-arid*, *arid*, *semi arid*, *dry subhumid*) present different agro-climatic conditions. Therefore, it can be genuinely stated that, drylands management options and agriculture opportunities may be very different for one DLS than the others, for example sub-humid dryland system with rainfall between 200 mm to 800 mm

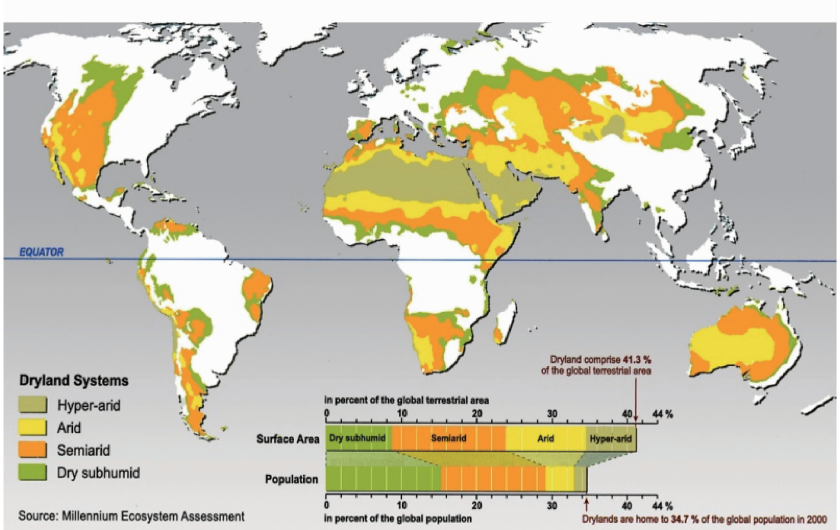

Fig. 1　Dryland systems (Source: Millennium Ecosystem Assessment)

per annum will require different management than the arid and hyperarid climates, where rainfall is less than 200 mm per annum. Food production systems in different DLS may be irrigated or rainfed, the latter is less productive. CGIAR defines dryland agricultural systems, where precipitation is low and erratic, and water supply is often the most limiting factor to agricultural production. They are characterized by persistent water scarcity.

3　Water stress and agriculture contribution to GDLA countries (e. g. GCC Countries)

The GDLA constitutes 45% to 60% nations with arid and semi-arid environments. Including into this are the Gulf Cooperation Council Countries (GCCC) Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. The GCC countries being located in DLS face various levels of water stresses (ESCWA, 2007) based on the available and renewable water resources of each country, such as critical (Kuwait and UAE—more than 10, 000 persons per million cubic meter, Mm^3), serious (Bahrain and Qatar—between 5, 000 and 10, 000 persons per Mm^3), significant (Saudi Arabia—between 2, 500 to 5, 000 persons per Mm^3), slight (Oman—less than 2, 500 persons per Mm^3).

Water scarcity, low arable land and climatic constraints restrict agriculture development in drylands such as the case of GCC countries, and hence, contribution of agriculture sector to GDP is very low. In 2008 the percentage of contribution of agriculture to GDP in GCC countries was less than 1% (Bahrain, Kuwait, Qatar), and 2. 0%, 2. 8% and 3. 9% in Oman, UAE and Saudi Arabia respectively. Similarly, the percentage of the population engaged in agriculture varies in different countries, e. g. , Qatar (0. 8%), Bahrain (1%), Kuwait (1. 1%), UAE (3. 2%), Saudi Arabia (5. 5%), and Oman (29. 2%).

4　Extent of marginal saline lands

Salt-affected soils (SAS) are also considered marginal due to high salinity and sodicity. They occur in DL and other systems. Review of literature revealed lack of recent estimates on the distribution of SAS globally and in GDLA member countries (Shahid, 2013; Shahid et al. , 2013a). Old estimates do occur, which are far from correct as salinity is dynamic and changing temporally. We summarized the global extent of marginal saline lands as well as in some GDLA countries. Of 13.2×10^9 ha of total land surface area, 7×10^9 ha is arable, 1.5×10^9 ha is cultivated, 25% to 30% of irrigated lands are salt-affected and commercially unproductive, and one billion ha salt-affected (Massoud, 1981). Of the cultivated lands, 0.34×10^9 ha (23%) are saline, and 0.56×10^9 ha (37%) are sodic. According to Szabolcs (1989) 10% of the total arable land is affected by salinity and sodicity extending into more than 100 countries and almost all continents. In Spain more than 20% of land area is desert or seriously degraded and nonproductive. In the Middle East 11. 2% area is affected by soil salinity (Hussein, 2011; Shahid et al. , 2010). Irrigated lands of Euphrates (Syria, Iraq) are seriously constrained by salinity. In Iran 14. 2% of the total area is salt-affected (Pazira, 1999). In Egypt 1×10^6 ha cultivable land along the Nile is salt-affected; salt accumulation in Jordan River basin adversely affected agricultural production in Syria and Jordan. In Iran 25×10^6 ha land is unproductive due to salinity. In Kuwait 12.1% area is affected to varying degrees of salinity (Shahid et al., 2002). In Abu Dhabi Emirate 35% area is saline to 50 cm depth (EAD, 2009a). In Africa 80×10^6 ha is saline, sodic, or saline/sodic, of which Sahel, West Africa, is most affected; in Asia, for example, in India, 20% of cultivable land is affected. In Pakistan 10×10^6 ha is affected. In Bangladesh 3×10^6 ha is unproductive due to salinity. In Thailand 3.58×10^6 ha, and China 26×10^6 ha are SAS. A total of 954.8×10^6 ha salt-affected soils are distributed into different continents (Kovda and Szabolcs, 1979), North America (15.7×10^6 ha), Mexico and Central America (2.0×10^6 ha), South America (129.2×10^6 ha), Africa (80.5×10^6 ha), South Asia (87.6×10^6 ha), North and Central Asia (211.7×10^6 ha), South-East Asia (20.0×10^6 ha), Australasia (357.3×10^6 ha), Europe (50.8×10^6 ha). Recent estimates do not occur and this is the area which needs consideration for update global extent and distribution of salt-affected soils. *GDLA member countries must coordinate their resources to estimate and map the extent and nature of salt-affected soils and marginal lands for better understanding and informed decision for food production.*

5 Biocapcity (BC) and ecological footprint (EF) of consumption and food security—GDLA member countries (Global Footprint Network 2010)

In order to assess the marginality of lands on a national level, it is important to determine, 1) biocapcity (BC) and, 2) ecological footprint (EF). Both are measured in terms of global hectares (gha). BC is the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans; using current management schemes and extraction technologies. The BC of an area is calculated by multiplying the actual physical area by the yield factor and the appropriate equivalence factor (Ewing et al., 2010; GFN, 2010), and presented as gha. EF is a measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates; using prevailing technology and resource management practices, it is measured in gha. The gha is normalized to the area-weighted average productivity of biologically productive land and water in a given year. Because different land types have different productivity, a gha of, for example, cropland, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland.

5.1 *Evaluation of GDLA member countries resource capacity to produce food within their boundaries*

To evaluate the national resource capacity of GDLA member countries to produce food, we attempted to examine the BC and EF of these 16 countries using EF calculator (GFN, 2010), to assess if these countries are eco-creditor or eco-debtors. Table 1 clearly illustrates that of 16 GDLA member countries, only 1 (Namibia) is eco-creditor; all others are eco-debtor. It is evident from these facts that almost in all countries the natural resources are not sufficient to offset the food requirements of the present and predicted population for the coming decades. There may be many factors behind this scene, like, lack of scientific soil information-national soil maps, soil, water and agriculture policies, water scarcity, marginal lands, scarcity of arable land, climate, lack of innovative research and development, networking, inadequate extension services etc.

Today, more than 80 percent of the world's population lives in countries that use more resources than what is renewably available within their own borders. These countries rely for their needs on resource surpluses concentrated in ecological creditor countries, which use less biocapacity than they have.

The above facts about GDLA countries such as GCC, with the current food import dependency exceeding according to the World Trade Organization 90 percent (Roy, 2010), neither the current quick fixes nor the piecemeal policy approaches will suffice to ensure human food security in the region. Hence there is urgent need for a paradigm shift that focuses not only on imports and agricultural policy, but also on a structure that integrates the latter with energy, population control, soil, water and agriculture policies, each of which directly affects food security (Spiess, 2011). With progressive salinization and desertification processes in the entire GCC region, the amount of arable land is projected to decrease even further and challenge of food security will remain to stay.

According to the Economist Intelligence Unit, GCC countries spending on food imports is projected to more than double from US $24.1 billion in 2009 to US $53.1 billion by 2020 (EIU, 2010). By contrast, the *International Trade Statistics 2009* published by the WTO shows that the UAE alone imported food worth US $15.28 billion in 2008, representing an annual percentage increase of 47 percent to 2007, while Saudi Arabia imported food worth US $ 15.25 billion in 2008, representing an annual increase of 29 percent (WTO, 2009). Some GCC countries have achieved noteworthy absolute progress in improving their Global Hunger Index (GHI) with the proportionate reduction of the undernourished population being the most significant driving factor among the best performers. For instance, between 1990 and 2009, Kuwait and Saudi Arabia saw some of the largest improvements on a global scale, by decreasing their GHI by 76.8 and 53.4 percent respectively (Von Grebmer et al., 2009). *There is urgent need for a paradigm shift to better understand the natural resources in GDLA member countries and develop soil, agriculture, water and food import policies.*

Table 1 EF and BC of 16 countries* in GDLA (GFN calculator)

Country in GDLA Network		EF per person (gha)	BC per person (gha)	If everyone in the world consumes like the country in the first column, the EF would be (see below) planets
GCC	Kingdom of Saudi Arabia	3.99	0.65	2.25
	Kuwait	9.72	0.43	5.47
	Oman	5.69	2.20	3.20
	Qatar	11.68	2.05	6.58
	UAE	8.88	0.64	5.00
Africa and Middle East	Algeria	1.65	0.56	0.93
	Egypt	2.06	0.65	1.16
	Iraq	1.42	0.24	0.80
	Jordan	2.13	0.24	1.20
	Libya	3.19	0.66	1.79
	Morocco	1.32	0.70	0.75
	Namibia	2.02	7.18	1.15
	South Africa	2.59	1.21	1.46
	Tunisia	1.76	0.96	0.99
Others	Kazakhstan	4.14	3.48	2.33
	Mexico	3.30	1.42	1.86

* Data of BC and EF for Bahrain do not exist.

5.2 *Ecological overshoot of planet earth use*

According to Global Footprint Network (2010), in 2008, the Earth's total BC was 12.0 billion gha, or 1.8 gha per person, while humanity's EF was 18.2 billion gha, or 2.7 gha per person. This discrepancy means that we are in an ecological overshoot situation: it is taking 1.5 years for the Earth to fully regenerate the renewable resources that people are using in a single year. Instead of living off the interest, we are eating into our natural capital. With business as usual, we will require over 2 planets by 2030, and 2.8 by 2050 (WWF, 2012). This fact can be related to overexploitation of Earth's resources, for example, cropland, this perhaps contributes significantly to transform good agricultural lands to become marginal. *We can only sustain food production if global consumption and production is in balance with the Earth's biocapacity.*

6 International perception of marginal lands and priorities

The CGIAR (1999) has set the research priorities for marginal lands to address poverty alleviation. To base research priorities, it is recognized that little has been done in ML, where most of the poor lives, and results in increase of resource degradation and subsequent yield decline. The mapping revealed $1,800 \times 10^6$ ha ML, housing $1,760 \times 10^6$ peoples, and rural poverty incidence to rural population is 630×10^6 on ML. Marginal areas is "*marginal*" for many reasons. In some cases, technologies can be developed that move lands from marginal productivity to higher productivity. The most obvious example is irrigation of deserts-where this is economically feasible and desirable. However, there are other, less obvious, but just as important examples, e.g., greater integration of range livestock systems into mixed farming or agroforestry technologies that increase productivity and farmer incomes, while at the same time reducing risk through diversification.

The UNEP stressed on maintaining and improving the capacity of the higher potential agricultural lands to support an expanding population. However, conserving and rehabilitating the natural resources on lower potential lands (marginal lands) in order to maintain sustainable man/land ratio is also necessary. The main tools in sustainable agriculture and rural development (SARD) are policy and agrarian reform, participation, income diversification, land conservation and improved management of inputs.

The FAO mandate is to raise levels of nutrition, improve agricultural productivity, better the lives of rural population and contribute to the growth of the world economy. According to FAO (1996), "*food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active, healthy life*".

The ICBA mandate is to help water-scarce countries improve the productivity, social equity and environmental sustainability of water use through an integrated water resources systems approach, with special emphasis on marginal resources (saline land and marginal quality water).

Climate negotiation in Durban—Climate Smart Agriculture (CSA)

In the changing face of climate and the vulnerability of marginal/drylands to climate change "*climate-friendly*" agricultural solutions have already been proposed for marginal lands. They include CSA, which has been advocated during the last climate negotiations in Durban (South Africa) as instrumental in achieving many aims.

7 Challenges of marginal dry lands for food production

Marginal drylands are constrained by, *defining marginal lands*, lack of scientific soil information, lack of soil and land use policies, increased water and soil salinity, water scarcity, climatic factors, poor management of natural resources, land degradation and desertification, low water use efficiency and productivity, poor soil fertility, poor extension services and post harvest losses and marketing. By 2050, rising population and incomes are expected to result in a 70 percent increase in global demand for agricultural production. Increased production is projected to come primarily from intensification on existing cultivated land, or on improved marginal lands, with irrigation playing a key role.

7.1 *Pragmatism about marginal lands*

Marginal lands are distributed in the entire world, regardless of climatic conditions and geographical occurrence. However, the criteria of marginality may vary based on their specific use. In Indonesia, three types of land not used for agriculture are known as, *marginal land* (unproductive land with high acidity), including swampland, wetlands and peat forests, as well as dryland on acidic soil, such as mountain areas; *critical land* (ecologically degraded land as a result of intensive agricultural practices, and which is no longer suitable for agriculture), and *sleeping land* (temporarily uncultivated land, but critical for indigenous communities that practice shifting cultivation and hunting) (Anderson, 2012). The CGIAR (1999) uses different names (*favoured, marginal, fragile, and degraded*) to designate lands in terms of their production capacity.

Lands may be marginal for agriculture production, but may be important from biodiversity context, and may have some endangered, flagship or nearly extinct species, and hence this land will be considered vital for biodiversity conservation, and should avoid any other use and must be well protected, otherwise there will be biodiversity loss in the planted area. Similarly a saline land with salinity of 5 dSm^{-1} will be marginal for vegetable crops such as beans (threshold salinity 1 dSm^{-1}), but suitable resource for forage production such as barley (threshold salinity 8 dSm^{-1}), and sorghum (salinity threshold 6.8 dSm^{-1}) (Maas, 1990). So the definition should be taken from a specific perspective. Under such conditions, where land resources are affected by salinization, which is usually the case in poorly managed irrigated agriculture (saline and brackish irrigation water) regions, the diagnoses of salinity problem become prime importance for proper crop selection for better production. It has been experienced that such an important component is mostly missing and is vital for sustainable food production. *Crop selection based on salinity diagnostics is essential for sustainable food production from marginal lands and water resources in dry land irrigated regions.*

7.2 *Need of national soil information and review of soil and agricultural policies*

High-quality land is a finite resource, and our demands on this resource are increasing. The average area of agricultural land per capita across the world has halved from 1961 to 2005 (Schoknecht, 2013) and this trend is expected to continue. The bulk of the world's most productive lands have already been utilized, and there is likely to be an increasing move to more marginal lands of lower quality. As the world moves towards using more land for agricultural production, it is essential that we know where the best land is, the opportunities it offers and its risks.

This is where fundamental land resource information, such as that collected in national soil inventories is critical for planning future developments in a sustainable way (Shahid et al., 2013b; Shahid et al., 2013c). The national soil surveys of the Kingdom of Saudi Arabia (MAW, 1985), Oman (MAF, 1990), Kuwait (KISR, 1999), Qatar (MMAA, 2005; Scheibert et al., 2004), Dubai (DM, 2004), Abu Dhabi Emirate (EAD, 2009a), and Northern Emirates (EAD, 2012) deliver soil and land resource dataset at a scale, accuracy and consistency required to support land use planning and policy development, and are significant achievements that should be applauded. The opportunities provided by this comprehensive information to achieve sustainable development are immense. To be successful, this process needs to engage government, academia, private sector and the community. These soil inventories provide science based information, including soil maps showing distribution of different soil types at national level, identifying soils having high potential for irrigated agriculture (KISR, 1999; Scheibert et al., 2004; EAD, 2009a; EAD, 2012), land degradation and soil salinity maps (KISR, 2009; EAD, 2009, 2012), suitability maps (rangelands, wildlife habitats, forestry plantation), and sources map (anhydrite, gypsum, carbonates, sands). Once these sources are used in land use planning, better results can be achieved leading to food security and environmental protection. Most of the GCC countries have completed national soil maps. The interpretation of national soil maps and associated soil mapping units for irrigated agriculture suitability identified areas (Saudi Arabia, 13.7%; Oman, 7.07%; Kuwait, 35%; Abu Dhabi emirate, 5.4%; and Qatar, 3.9%) having high to moderate suitability for large-scale irrigation farming. The question is, do the GCC countries have sufficient water resources to farm these areas?

It is recommended that GDLA member countries assess their soil resources and information linked for access to GDLA member countries. ICBA has wide experience in assisting different countries in developing national strategies, such as Abu Dhabi Water Resources Master Plan (EAD, 2009b), UAE Water Conservation Strategy (MoEW, 2010), Oman salinity strategy (MAF-ICBA, 2012) and national strategy to improve plant and animal production in the UAE (MoEW, 2013). It is necessary to develop soil, water and agriculture policies if do not exist, or review the existing ones in the context of sustainable food production from available national resources.

7.3 *Competition between food production and biofuels-overexploitation of marginal lands on the cost of prime lands*

Marginal lands have gained importance from scientific and political debates when debated to be used for biofuels. The Senator Zuburi (author of the Biofuels Law in Philippines) promoted biofuel crops on marginal land at the 2008 World Biofuels Conference. Similarly India supported conversion of 14×10^6 ha so called "*wastelands*" to Jatropha for biodiesel. Mozambican President, Armando Guebuza, has called to grow agrofuels crops on "*marginal lands*". The main objective of these recommendations is to save prime lands for agriculture, so that there is no competition of agrofuels with food production. *ICBA believes that the use of prime land for biofuels will create food security issues in poorly developing countries and recommends using real marginal lands to avoid competition with food production.*

The term *marginal* is overwhelmingly used to justify "*wider strategy*" for industrialization (biofuels, agrofuels) of global agriculture, such as, among others, wide spread of soya production in ML in the north of Argentine. It is not always possible that agrofuels or biofuels can be successfully adopted on all marginal lands. It is realistic to think very carefully, to distinguish between "reality" "promises" and dangerous exploitations (FACT, 2007). Jatropha is often cited as ideal for ML (poor soil with little water). Rajagopal (2007) indicates that yields from jatropha vary greatly, depending on soil fertility and water. It is true that optimum oil production from jatropha requires significant rainfall of upto 1,000 – 1,500 mm per hectare-amounts that fall well outside what is usually considered "*marginal land*". The investors, therefore, are aware of such prime requirements, and choosing jatropha cultivation on well watered and fertile lands, and not "*marginal lands*", which is highly questionable. Fragione et al. (2008) reported all current agrofuels accrue a "*carbon debt*" of decades and centuries.

7.4 *Food and nutrition security*

Prevalence of undernourished varies in different regions (Bantilan et al., 2006). Today almost 1 billion people are undernourished, particularly in sub-Saharan Africa (239 million) and Asia (578 million). In developing countries, even if agricultural production doubles by 2050, one person in twenty still risks being undernourished-equivalent to 370 million hungry people, most of whom will again be in Africa and Asia. For nutrition to improve and for food insecurity and undernourishment to recede, future agricultural production will have to rise faster than population growth, which is only possible through innovative agriculture research whereby biotechnology and molecular biology can play an important role. This will have to occur largely on existing agricultural land, and through improving marginal lands for agriculture production. The FAO's mandate is to raise levels of nutrition, improve agricultural productivity, better the lives of rural populations and contribute to the growth of world economy (FAO, 1996).

7.5 *Foreign investments in agriculture sector*

In 2007 and 2008, there were food price shocks, as grain prices soared. Since then, the growing competition for land and water are now thrown into stark relief as sovereign and commercial investors begin to acquire tracts of farmland in developing countries (von Braun and Meinzen-Dick, 2009). These deals raised grave international concern. The reasons being, to secure food supply by increasingly food-insecure nations, the surging demand for agrofuels and other energy and, the sharp rise in investment in both the land market and the soft commodities market. A dangerous element of the land grab trend is the shift from domestic to foreign control over food resources and food-producing lands. Land deals diminish the possibility of reaching food self-sufficiency for poor nations and some view land concessions as governments out-sourcing food at the expense of their most food-insecure citizens. Importantly, most of the target "host" countries themselves are net food importers or even emergency food aid recipients (Daniel, 2011). ICBA perceives such situation through using marginal lands (by foreign investors) for food production and leaving the prime land for the host countries. The investors are capital rich; they can approach ICBA to help in bringing the marginal lands into production through using its wider international experience in reclaiming marginal lands and introducing biosaline agriculture. The GDLA may negotiate with the member countries in this regards for a win-win scenario.

8 Best management practices for sustainable food production in marginal lands

Package of best management practices (BMPs) for food production from good and marginal lands (rainfed & irrigated) have been globally used since many decades, so is the case with ICBA since inception in 1999 (Shahid et al., 2011). ICBA worked in almost 35 countries and transferred biosaline agriculture production systems. The most important component of the use of BMPs is to assess the resource (for example, soil and water) capacity for a particular use, and based on the assessment BMPs package should be developed, which will be site/area specific, and this package once tested in a certain area can be transferred to other areas, for example, testing in one GDLA country may be equally good for transfer of technology to other country, with the condition that similar soil and climatic conditions are existing.

Following are some BMPs recommended for food production in GDLA member countries.

8.1 *Development of national soil, water and agriculture policies*

There is strong need in GDLA member countries to develop soil, water and agriculture policies, or review and revise the existing ones based on the food demand of ever increasing population and climate change impact. A recent example is from Oman, where ICBA jointly with Ministry of Agriculture has developed Oman Salinity Strategy to improve agriculture production (MAF-ICBA, 2012). One of the most important elements "soil" is missing in most of the debates around water scarcity and climate change. Soil management is fundamental for food security, for water security and for storing carbon and reducing global greenhouse gas emissions. This situation is changing internationally, as the importance of the land in supporting our future survival and prosperity is increasingly realized. A soil management and use strategy providing a clear purpose and direction for policy development and a framework to coordinate activities is essential. The GDLA member countries should review carefully the present soil policies and develop them in sustainable ways, to cope the changing face of climate change and increasing food demand of ever increasing population, restoring the productive capacity of marginal soils and, putting in place robust and resilient systems of marginal land use and management that prevent further soil degradation to a level where U turn is not possible. ICBA has prepared water and salinity strategies for UAE and Oman (EAD, 2009b; MoEW, 2010; MoEW, 2013).

8.2 *Diagnostics of the problem rendering the land to be marginal*

Problem diagnostics should be an essential component of BMPs to prepare management options. The problems/constraints affecting food production in an area or a country vary. The problems could be, e.g. soil erosion and loss of nutrients (rainfed agriculture), and soil salinization (irrigated agriculture), and the latter is more prevalent in GDLA member countries where irrigation is accomplished using saline/brackish waters, such as the GCCC (Bahrain, Kuwait, Oman, Saudi Arabia, Qatar and UAE). This is the domain of ICBA work. Soil salinization in agricultural fields is increasing due to forced intensification of agriculture for short-term benefits, ignoring long-term consequences for soil services to meet food demand, and poor management of soil and water resources. Soil salinization has been identified as the major cause of declining crop yields in drylands areas where irrigation is accomplished using saline water. It is, therefore, very important to understand the salinity hazard spatially and temporally at the regional-and national-farm levels (Shahid, 2013; Shahid et al., 2013a).

Soil salinity is dynamic and varies widely vertically, horizontally, and temporally. Many considers soil salinity a uniform feature in a soil profile, Shahid et al. (2009) while working on saline-sodic soils of Pakistan proved soil salinity, a layered feature down the profile. For proper use of marginal saline lands it is essential to measure, map and monitor soil salinity for resource base management. In agricultural fields, an effective salinity measurement will identify root zone salinity and help plan to assure root zone salinity is below the crop threshold level. At the regional and national level, such salinity mapping (Shahid et al., 2002; Shahid et al., 2010) program helps policy-makers to take necessary and timely action to tackle the issue to avoid spreading to other areas that may have significant impact on national economies through degrading soil resources. *National soil salinity mapping in GDLA member countries will identify marginal saline lands and those at threat, leading to better resource management for sustainable food production.*

8.3 *Informed decisions to develop BMPs for food production in marginal saline lands*

Crops can tolerate salinity (water & rootzone salinity) up to certain levels without a measurable loss in yield (this is called threshold salinity level). At salinity levels greater than the threshold, crop yield reduces linearly as salinity increases. Using the salinity values in a salinity/yield model developed by Maas and Hoffman in 1977, predictions of expected yield loss can be made. Maas and Hoffman expressed salt tolerance of crops by the relationship,

$$Y_r = 100 - s(EC_e - t)$$

where Y_r = percentage of the yield of crop grown in saline conditions relative to that obtained on non-saline conditions; t = threshold salinity level where yield decrease begins; s = percent yield loss per increase of 1 EC_e (dSm^{-1}) in excess of t. Farm level salinity mapping help select salt tolerant crops (from tables published by Maas, 1990) and management options.

8.4 *Innovation and research (Molecular biology/biotechnology)*

Molecular biology can play a key role in developing salt and drought tolerant crop varieties resilient to marginal (drylands, saline lands) environments for food production and as adaptation to climate change. Shahid (2012) has recently identified some of the innovative researchable ideas that, he is optimistic, can lead the way to green revolution, and hence meeting the food demand of ever growing population. It should also be remembered that, the ability of any country to take advantage of the opportunities and to avoid drawbacks (e.g. climate change impact, marginal lands) depend on the availability of adequate resources and quality research base, same applies to GDLA member countries to rethink their research priorities for better use of resources for food production.

Innovative researchable ideas that may lead to green revolution (Shahid, 2012) are as following:

1. Develop cultivars-lower water use efficiency in early season, stomata closure midday.
2. Introduce Biological Nitrogen Fixation (BNF) character in non-leguminous crops.
3. Enhance sunlight efficiency for photosynthesis.
4. Introduce resistant to heat shock, salinity and drought tolerant varieties.
5. Develop viable options to maximize yield under warmer and water deficit conditions through breeding and agronomic research.

8.5 *Integrated Soil Fertility Management (ISMF) in marginal environments*

The significance of sustainable agriculture, food security and smallholder farmers was formally recognized in the final Rio +20 text. The food security section explicitly acknowledges the link between food security and agriculture. The concept of sustainability, when applied to agriculture, implies that key resources such as soil, nutrients and water cannot be consumed exhaustively. There is a need to replenish the soil's nutrients, which can be achieved through the right use of fertilizers that will ensure sustainable yields.

Rainfed agriculture in drylands gives low productivity compared to irrigated, reasons being low fertility due to erosion, unreliable rainfall, poor soils and low management practices. ISFM is an effective strategy for sustainable agriculture on eroded dryland soils. In sub-Saharan Africa, nutrient output from all sources currently exceeds inputs by a factor of three or four, the net loss being estimated at some 10 million metric tons per year (UNEP, 2013). As a result, more marginal lands were put under agriculture use, thus created further land degradation.

Replenishment of soil nutrient pools, on-farm recycling of nutrients, reducing nutrient losses and improving the efficiency of inputs on degraded soils is much more important than on normal soils. ISFM combines the use of both organic and inorganic sources to increase crop yield, rebuild depleted soils and protect the natural resources (Evans, 2009). Organic amendments increase the efficiency of inorganic fertilizers through positive interactions on soil biological, chemical and physical properties. The ISFM optimizes the effectiveness of fertilizer and organic inputs in crop production.

To be successful in nutrient replenishment for sustainable crop production 4R strategy need to be used. 4R strategies promote the use of Right (fertilizer) source at the Right Rate, at the Right Time, and in the Right Place.

8.6 *Integrated Soil Reclamation Program (ISRP) and introduction of biosaline agriculture for marginal saline lands*

Sustainable food production "*sustainable agriculture*" from marginal lands is most likely to be achieved through ISRP and natural resource management (NRM) where long-term condition of the resource is built in as a core consideration. Thus, crop production in marginal lands can only be successful, if soil is dealt with in a holistic approach "*integrated approach*" including all aspects of soil, water, plants and climatic aspects etc. Many have the misconception about the biosaline agriculture (BA), which is complete solution of using marginal lands and waters. The biosaline agriculture is one of the components of ISRP including physical, chemical, hydrological and biological methods. Using salt-tolerant crops (BA) and ignoring other soil aspects will convert good soils to marginal, as the soils will have high risks of salinization while using marginal (saline/brackish) waters. In order to implement ISRP, it is important to diagnose the problem of soil salinity and sodicity, as well as in depth (to atleast 200 cm depth) investigation to identify if there is barrier (hard/dense layer, water table etc.) to root penetration and crop production.

It should be remembered that there is no single or combination of techniques, suitable for all marginal (saline, saline-sodic, sodic) soils, suggesting the formulation of combination of techniques, which is site specific, and should be only used in other areas where similar soils and environmental conditions may be existing. ICBA has sufficient expertise in the diagnostics of the problem, developing integrated reclamation strategy and implementation to transform marginal soils to good quality for crop production, using methods, such as physical (leveling, salts scrapping, tillage, subsoiling and sanding); chemical-use of soil amendments (elementals S, acids, gypsum) based on gypsum requirements (GR) to rectify soil sodicity problem and to improve soil health; hydrological (irrigation systems- surface, flood, basin, drip, sprinkler, sub-surface irrigation etc., leaching and drainage) and biological (biosaline agriculture-salt tolerant crops, serial biological concentration approach (Shahid and Rahman, 2011; Shahid et al., 2011).

The main objectives of management and reclamation should be to bring more soils under cultivation; to increase the yield per unit area; to increase the water and fertilizer use efficiency and to improve livelihood of the farmers. Efficient, effective and long-term reclamation of saline soils require the lands to be well leveled before leaching is initiated, additional supply of good quality water is required and good sub-surface drainage is essential.

8.7 *Climate Smart Agriculture (CSA) for food security and to address climate change issues*

Climate Smart Agriculture seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage on farmland. Climate-smart agriculture includes proven practical techniques—such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing, and improved water management—but also innovative practices such as better weather forecasting, early warning systems and risk insurance. It is about getting existing technologies off the shelf and into the hands of farmers and developing new technologies such as drought or flood tolerant crops to meet the demands of the changing climate. It is also about creating and enabling policy environment for adaptation (World Bank, 2011).

8.8 *Conservation Agriculture (CA)*

Conservation Agriculture is part of Climate Smart Agriculture (CSA). CA recognizes the importance of the upper 0 – 20 cm of soil as the most active zone, but also the zone most vulnerable to erosion and degradation. By protecting this critical zone, we ensure good agriculture and environment.

The main principles of CA are (Dumanski et al., 2006)

- Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through zero tillage systems, to ensure sufficient living and/or residual biomass to enhance soil and water conservation and control soil erosion.
- Promoting a healthy, living soil through crop rotations, cover crops, and the use of integrated pest management technologies.
- Promoting application of fertilizers, pesticides, herbicides, and fungicides in balance with crop requirements.
- Promoting precision placement of inputs to reduce costs, optimize efficiency of operations, and prevent environmental damage.
- Promoting legume fallows (including herbaceous and tree fallows where suitable) composting and the use of manures and other organic soil amendments.
- Promoting agroforestry for fiber, fruit and medicinal purposes.

8.9 *Capacity Building (CB) of extension staff and farmers*

Capacity Building of the extension staff and the farmers is very important to gain benefits from the new technologies. These innovative new technologies must reach to the farmers soon after the release.

The CB is very strong component of Innovation and Research program at ICBA (ICBA, 2012). From 2000 to 2012 ICBA has conducted many training programs at its headquarters in Dubai and internationally in partnering countries. These training programs were conducted mainly on plant production systems in marginal lands, soil and land use management, socio-economic aspects, and water resources management. A total of 1, 184 trainees from different regions receive training at ICBA HQ (567) and in partnering countries (617).

8.10 *Strengthening of research-extension-farmers link*

A strong link of research-extension-farmers should be maintained at all times to benefit the end chain member (farmers-the stakeholders). Advisory program should be developed to help farmer's plan food production in their farms. The extension staff in collaboration with research institutes should demonstrate the technologies through exhibitions, demonstration days at the farmer's field, introductory brochures of new technologies and crop varieties, integrated pest management, post harvesting challenges or salinity control, irrigation and nutrient management at the farm level.

8.11 *Creation of GDLA strategic food reserve*

Given these existing and predicted challenges in GDLA member countries, the GDLA should be seeking new options for food production and food security, such as through intensification in local food production using high-tech multipronged approach (rationale use of soil resources, modern irrigation systems, protected agriculture, water conservation, sector wide water reforms, use of alternate water sources and improved varieties etc.); continuing food import; outsourcing food production to countries which have comparative advantage for agricultural expansion; leasing farmland abroad, and through creation of GDLA Strategic Food Reserve. There are however, strengths, weaknesses, opportunities and threats of achieving food security by above ways. The creation of GDLA strategic food reserve can assure food security for a certain period in case of political instabilities and climate crises.

9 Recommendations

Following are the recommendations to be considered by the GDLA, its member countries and international partners, to realize the sustainable use of marginal soil resources in GDLA member countries for food production.

A. Recommendations to GDLA:

- Promote sustainable land management through the inventory and assessment of soil, land resources and their use, and link information
- Take an initiative to map marginal lands and their types to assess their biophysical fitness in supporting competitive agriculture
- Build a database, design the architecture of the GDLA Soil Information System (GDLASIS) and share with member countries
- Support monitoring activities at the national level to identify land degradation, desertification trends in GDLA member countries

- Establish strategic food reserve for GDLA member countries
- Create and centralize knowledge sharing network between member countries for technology adoption
- Host international (every three years) conferences, and capacity building programs in member countries for information sharing
- Build a GDLA network (partnership) among the member countries to develop synergies for sustainable food production
- Foresight exercise and joint planning with the Association of International Research and Development Centers for Agriculture (AIRCA) a newly formed alliance with nine founding members (AVRDC—Asian Vegetable Research and Development Center, CABI—CAB International, CATIE—Tropical Agricultural Research and Higher Education Center, CFF—Crops for the Future, ICBA—International Center for Biosaline Agriculture, ICIMOD—International Centre for Integrated Mountain Development, icipe—African Insect Science for Food and Health, IFDC—International Fertilizer Development Center, INBA—International Network for Bamboo and Rattan)

B. Recommendations directed to member countries of the GDLA:

- Lobby the government to invest in innovation and research in agriculture sector to enhance food production
- Assure there is strong link between research-extension-farmers for the adoption of new technologies and advisory services
- Explore new technologies (CA, ISFM, CSA, ISRP) and adopt appropriately to enhance their local production
- Assure regular trainings on new technologies adoption
- Share technical resources between GDLA member countries

C. Recommendations directed to partners in development:

- Develop strong consensus to provide technical support to GDLA in their areas of expertise. This can be achieved through offering packages of technologies, and conducting training programs based on GDLA countries demand
- Help GDLA member countries in restructuring policies
- Create a joint forum of partners reviewing the progress of the GDLA program on annual basis, and providing recommendations for improvement

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