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The Effect of Climate Change on Plant Genetic Resources and Agriculture in Oman

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Abstract **– The Sultanate of Oman is the country of vast biodiversity in the Arabian Peninsula, which reflects Oman's unique place between two geographic regions northern part closely resembles Asia whereas southern part has similarity to Africa in its climate and physiographic regions. It is clear from the findings of the IPCC (Intergovernmental Panel on Climate Change)that the Sultanate of Oman is vulnerable to the potential impacts of climate change like the ones being experienced as increased average temperatures, less and more erratic precipitation, sea level rise (SLR) and desertification. In 2007 and 2010 Oman suffered heavily from severe tropical cyclonic storms named as *Gonu* and *Phet*. They had a significant adverse effect and caused heavy damages on agriculture and plant genetic resources (PGR) which in turn affected the country's economy. The objectives of this study are to highlight the general information of the climate change and its impact on agriculture and its plant genetic resources (PGR) in Oman. Besides, this report emphasizes on the most important activities of various ministries and national institutions/ organizations related to the environment and climate change and their role on mitigating the risk of these changes. The Ministries and other national institutes/ organizations have carried out rapid assessment and initiated preliminary studies on the identification of climate change impacts which indicated that Oman is likely to be affected by climate changes in future. From the review of reports and other documents it can be concluded that Oman is vulnerable to climate change, its agriculture and plant genetic resources are under increasing pressure and increasing population, urbanization and other factors along with their interaction with climate change and the environment are playing significant roles in causing impacts on both agriculture and its PGR.**

Keywords **– Biodiversity, Climate Change, Impacts, Plant Genetic Resources, Agriculture, Oman**

I. INTRODUCTION

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published in 2007 indicated that the Earth's climate is changing as a result of human activities. The last sixty years were the warmest in the last 1000 years [1-2].According to the findings of the Intergovernmental Panel on Climate Change (IPCC), it is evident that the Sultanate of Oman is vulnerable to the potential impacts of climate change, the most significant being increased the average temperature, less and irregular rainfall pattern and sea level rise (SLR). These in combination have affected coastal region, people and ecosystem. This also leads to desertification. These impacts will cause serious damage to the economy of the world as well as Oman which already suffers from aridity, soil salinity, recurrent drought and water scarcity. These all threaten to country's food security. Recently, German Watch has ranked Oman as 40 in terms of Global Climate Risk Index based on 1990-2008 data [3] in comparison with Bangladesh and UAE, which were ranked 1 and 156, as examples.

There is a significant concern about the impact of climate change on plant genetic resources and agricultural production worldwide. Climate change affects dynamics of ecosystem in various ways such as shift in the distribution of a wide range of crops and losses of cropping areas. Rise in temperature and change the environment could help in the spread of invasive alien species, pests and parasites. As ecosystems change, the distribution of disease vectors is likely to be affected with consequences for epidemiology of many crops and livestock disease [4]. The climate change also threatens strategic reservoir of the genetic resources of crops and livestock which need adoption for production. It also affects the aquaculture and marine life and distribution of aquatic diseases, parasites and toxic algae blood.

Climate also affects many environmental aspects, including the temperature, oxygenation, acidity and salinity. The effect on agricultural production is expected to vary by crop, locations as well as the degree of warming and the direction and magnitude of precipitation change [5-6].The effects of climate change are expected to reduce agricultural productivity, stability and incomes in many areas of the world. The problem of climate change was identified as early as the nineteenth century. This issue did not appear on the international scientific and political agenda until the first world conference held in 1979 [7]. In 1992, the world gathered at the Rio Earth summit, the first conference on climate change adopted by the United Nation and put it in framework conservation of climate change (UNFCCC). Little attention has been given since then to the effect on genetic resources for food and agriculture by the UNFCCC process. In the 2007 Bali Action Plan, adaptation for PGR became one of the significant changes for world attention in addressing the effect of climate change on PGR in general and agriculture in specific. The recent outbreaks of harmful algal blooms along the coast of Oman were speculated to be linked to recent climate change [8] while 27-year rainfall data in Oman did not provide any clue for significant increasing or decreasing trends [9]. However, it was concluded that future climate might present an increase in water resources

of Oman [10] whereas the recent decline (based on 1983-2007 data) of chill hours in JabalAkhclar mountains was thought to seriously affect the local fruit production [11]. Research is being conducted on issues such as green roof, fog water collection, managed aquifer recharge and similar topics at Sultan Qaboos University, which might help the government in selecting appropriate strategies for climate change mitigation and adaptation in Oman.

In respect of economic impacts of climate change, a few studies provided reviews [5-6]. The important findings were – i. Over the next century, regional increases and decreases associated with climate change as now foreseen are not expected to result in large changes in global food production or any large global economic disaster in total food production. This likely would likely occur because the projected range of climatic alteration is less that the range of temperatures, now experienced across productive areas of global agriculture, ii. Impacts on regional and local food supplies in some low latitude regions could amount to large changes in productive capacity and significant economic hardship, iii. Climate induced productivity changes that are harmful for consumers are typically to producers. In several studies of agriculture that include price effects, reductions in crop yields indicate that consumers would pay higher prices and receive smaller quantities of agricultural goods, and would thereby suffer economic losses. However, because consumers' demand for most crops is relatively inelastic with respect to price, declines in supply result in even greater percentage increases in prices. Consequently, producers are projected to gain on average from revenue increases, iv. Climate change can influence prices, total acreage and market signals. The importance of market-level changes were illustrated in the estimates reported earlier [5].

Climate change induced change in total welfare and productivity estimates were negative, because the yield losses have been reduced due in part to milder temperature and precipitation estimates emerging from the global circulation models and enhanced CO2Fertilization effects. Climate change is likely to shift the comparative advantage of agricultural production regions. Such shifts are likely to alter the places in which specific crops are grown, both within countries and internationally, altering patterns of trade in agricultural commodities among regions and countries.

The economic consequences of yield changes will be influenced by adaptations made by farmers, consumers, government agencies, and other institutions. Farmers may adapt by changing planting dates, substituting cultivars or crops, changing irrigation practices, and changing land allocations among crop production, pasture, and other uses. Consumers may adapt by substituting relatively low priced products for those that become relatively high priced as a result of climate change effects.

Changes in climate are expected to affect the productivity and aggregate demand for factors of production such as water, labor, energy, and equipment. Climate change could be analogous to technological change in agriculture, which can increase or decrease total factor. The objective of the present investigation is to highlight the general information of the climate change and its impact on agriculture and plant genetic resources in general considering the relevant data in Oman, as a case study besides pinpointing the most important activities of the institutions related to the environment and climate change and their role by mitigation the risk of these changes in Oman.

II. General Information on Oman and Current Knowledge About the Climate Change

The Sultanate of Oman is the third largest and probably the most diverse country in the Arabian Peninsula. This condition is chiefly due to the location of Oman between latitudes 16°40′& 26°20′N and longitudes 51°50′ & 59°40′E in the North Eastern corner of the Peninsula; and due to its geography, and topography over an area of 309500 km^2 with a territory extending. from a long coastline of 3165 km in connection with three seas that are the Arabian Gulf, the Sea of Oman and the Arabian Sea with islands and islets to the mountain range (15% of the country surface area) that includes at 3000 meters at Jabal Shams, through salt flats (Sabkha), lagoons (Khwars), large gravel desert plains (Seih), sand dunes, undulating formation of sand dunes, endless desert of Rub'wEl Khali (Empty Quarter) covering the southwest of Oman, and wadis (dry riverbeds) (79% [desert plains and sandy areas] of the country surface area). The agro-biodiversity area covers 8% of country surface area and the coastal zone covers 3% only [12].The agro climatic regions are recognized in Oman based on the parameters which influence crop water requirement and efficient use of water, land and water resources potential and cropping patterns:

Batinah Coastal Plain: This part of Oman is considered the principal agricultural area with 60% share in national agriculture production. The climate of Al Batinah is hot during summer, and temperature reach 48-50^{0}Cwith relative humidity around 90%, while the winter temperature ranges from 15-24^{0}C. the average rainfall is about 100 mm, mostly distributed between November and February. The PGRFAand farming here have been affected due to change the quality of irrigation water due to seawater intrusion.

Interior Oman and Al-Dhahirah plains*:* The climate of this zone is characterized by high temperatures during summer and slightly lower humidity prevails as compared to that in the Batinah coastal plain. Al-Jabal Al-Akhdar being at an altitude of 3000m constitutes a unique climate zone as compared to any other region of the sultanate. It is characterized by lower winter temperatures, which satisfy the chilling requirements of number of temperate deciduous fruit and nut trees such as pomegranates, peaches, apricots, apple, pears, walnut and almonds. The summer temperatures average 30^{0}C. Annual rainfall 300mm is significantly higher than elsewhere in Oman, with the exception of Dhofar Jabal, and it is distributed throughout the year.Al-Sharqiya Plains, agriculture is

concentrated around Ibra, Ad-Darize and Al- Wafi. It has 26 oases irrigated mainly by the falaj system.

Southern Oman plains and mountains : They occupy approximately one third of the area of the Sultanate. Apart from the coastal plain extending from Raysut in the west past Salalah, the woody hills reach up to 1500m elevation behind plain constitute a separate climatic zone. The southern slopes of the hills known as the 'Jabal" are rather steep, deeply incised narrow wad is, and receive southern monsoon rains. The northern slopes called 'Najd' are much gentle and the wad is dissecting them are wider and less deeply incised. Salalah plain, is located in the coastal area of the southern province of Dhofar. Dhofar is the only region in Oman to benefit from a substantial amount of rainfall from the southern monsoon Kharif. Dhofar Jabalrange composes a separate agro-climatic zone of their region. Rainfall is particularly high, ranging from 600 to 700mm, the highest as compared to any other area in the country, supporting permanent vegetation cover.

III. The State of Agriculture and Plant Genetic Resources in Oman

The State of diversity and relative importance of major crops for food security

The soil survey of Ministry of Agriculture and Fisheries in 2004-2005 estimated that 2.223 million hectares of Oman are suitable for agricultural activities (7.4% of the surface area of the country) [13]. Irrigated land area is about 72,820 ha and planted with various crops. Oman has a wide diversity of crop plants for food or feed purpose in addition to other human use. Among the important crop plant species are 12 field crops, 7 vegetables, 11 fruit trees, 20 forest trees and rangeland pasture species and a few aromatic and medicinal plant species which are known to be grown in the Sultanate since time immemorial. Oman has not only several locally adapted cultivars and land races of crop species but also unexplored wild relatives of some crop plants that may be an irreplaceable source of diversity for traits useful for crop improvement. There are evidences of an increasing pressure on this diversity from several factors, such as soil and water salinity, drought, scarcity of irrigation water, and high grazing pressure by increased number of livestock. These factors are inevitably posing a serious threat to the very survival of Omani indigenous crop species and cultivars. It is a challenge for the institutions of Oman to revert this trend through an integrated and balanced approach, which takes advantage of the expertise and capacity of all national stakeholders. The summary of area and production of the cultivated crop resources of Oman are presented in Table 1[14].

The state of diversity of wild plants harvested for food and agriculture production

The biodiversity of Oman reflects its position between two biographic regions; northern Oman's biodiversity more closely resembles that of the Asian continent whereas southern Oman's biodiversity has the principal influence of African continent. Oman has many wild plants in its ecosystems that were earlier harvested for food directly or indirectly(Table2). Also, Oman is a home of 80 exclusive plants; that are not found in any other place in the world. Dhofar Provence has about 750 wild species [15].

The state of diversity of indigenous and exotic varieties

Farmers have been selected and conserved landraces and local cultivars in a dynamic way since they started cultivation of crops (Table 2). By growing a mixture of diversified local materials and, therefore, maintaining on-farm high inter- and intra-specific diversity, farmers throughout the years have been able to select varieties adapted to local environmental conditions and to reduce risks derived from too specialized farming systems [16].

Crop wild relatives

The crop wild relatives (CWR) constitute an important resource for improving agricultural production. An analysis of the flora from Dhofar region shows that there are over 750 species. Because of their natural adaptation to harsh environmental conditions, these species are expected to be extremely important sources for genes for the crops improvements targeting climate change and this can be of potential value of Oman agriculture. Existing flora of Oman, in particular in the Dhofar region, include crop wild relatives of several species used for food and agriculture. These include species belonging to different families and genera Table (2).

The plant agro biodiversity conservation strategy of Oman was developed. Accordingly, it was found that Sultanate of Oman has been characterized six different groups of plant diversity or six checklists created for crops, crop wild relatives, medicinal plant, forest trees, ornamental species in addition to socioeconomic plant species [15]. A summary of the checklist content is provided in Table (2)

Impact of climate changes and adverse weather conditions on the agricultural sector in the sultanate of Oman

In 2007 and 2010, Oman has suffered heavily from severe tropical cyclonic storms named Gonu and Phet. They had significant adverse effects and caused heavy damage and many causalities', leaving many coastal roads flooded damaging both public and private properties, and damage to crops and their impact on the income and livelihood of farmers and erosion hectares of fertile agricultural farm lands located along the wadis/ valleys leading to lodging of around a quarter of a million trees during 2010 and the destruction of much of the farms drowned besides washing away of large numbers of farm animals. It was too early to say whether these events are related to climate change but there is no drought that such events have a severe effect on society and the government to take the issue of climate seriously [17]. According to climate forecasts, it is expected that the phenomenon of repeated adverse weather conditions in the future with precipitation leading to large amounts of water and severe hurricanes, which increase the risk of erosion / soil erosion, destruction of vegetation, crops and livestock.

These occurrences confirm predictions that certain changes could occur due to climate change such as rate of

temperature rise in the overall rate of some countries, two and six degrees Celsius by the 2100 [38], average annual precipitation reduced by a remarkable and repeated and extended periods of drought and increase the rate of evaporation of water from the soil as a result of increasing temperature that would lead to rise of salinity in the coming years.

Climate change and global warming

Climate change is predicted to reduce agricultural production by 2% each decade this century [18] but with the ever increasing human population which is 7.26 billion today and predicted to be 9.6 billion by 2050 [19], there will be increasing demand to use the threatened PGR to increase agricultural production. The reduction in crops production is due to several reasons:i a change in the dates of cultivation of crops as well as the dates of harvest, ii. the season becomes shorter which would have impact on the crop structure in causing the low productivity of some crops, ii. the impact of global warming on the climate in general and water scarcity and drought and the increase of desertification and soil salinization, iii. increase in the rate of evaporation of water from the soil which is what is happening about water pressure and the rate of rise of salinity in coastal areas.

The impact of global warming on the climate in general which led perhaps to the possibility of the emergence of new pests and diseases in crops and this is associated with elevated temperatures and where there is no genetic resistance of traditional crops (indigenous crops) as in the case of the black stem rust disease (Ug99) for some strategic crops, particularly wheat, as well as the deterioration of some fruit trees, palm trees and there is the emergence and the expansion of the spread of new pests in the region which were not present earlier and might be more destructive to crops which could be also due to increased use of chemical pesticides and increased environmental pollution.

The biodiversity of Oman

Oman is an area of relatively high biodiversity, especially in the region with a higher level of precipitations. Terrestrial biodiversity is an important part of Oman's biodiversity as rangelands and woodlands are found to harbor a diverse array of plant species. Approximately 1,208 plant species were identified from the Sultanate of Oman [20].This has been updated and increased to 1,407 plant species [21]. Oman has a high percentage of endemics to the extent of seventy-eight species, forty-eight species near-endemics and sixty-three species are regional, endemic to the Arabian Peninsula [21].The Sultanate of Oman has a huge and untapped wealth of unique genetic resources that include over 1,200 species of plants.

Genetic threats to plant genetic resources:

Despite the important of agro biodiversity, there is an increasing PGR tax on extinction and genetic erosion within PGR tax a is due to a number of social, economic and ecological factors. The genetic threats to plant genetic resources in Oman have been summarizedrecently [15] as following:

i. CWR, MP, WHS and LR are each expected to be affected by climate change [22-26]. The changes that are expected to augment the risk of pest and disease spread and to affect precipitation regimes and cropping patterns in cultivated species [27-28]. LR are being lost due to their replacement with modern cultivars, the pressure of changing markets, as well as family needs and aspirations, which may include the abandonment of traditional practices; while CWR, MP and WHS, like other wild plant species are threatened by the loss, degradation and fragmentation of their natural habitats and competition from alien species;
ii. CWR are often associated with disturbed habitats such as field margins, forest edges and roadsides, and these populations are not being adequately conserved by ecosystem conservation agencies;
iii. LR are often associated with low-input traditional farming systems, many of which are being converted to more intensive high-input systems;
iv. CWR, MP, WHS and LR diversity suffers from a lack of knowledge regarding their breadth, location and real use potential; for example, inventories are lacking for most countries and conserved CWR, MP, WHS and LR diversity is largely uncharacterised or unevaluated [29]. In particular, the lack of knowledge on how many traditional seed-saved varieties remain extant as well as on their traditional cultivation practices has been a severe constraint in their conservation and utilization. LR are commonly maintained by older people and diversity is being lost as their cultivation is not being undertaken by younger generations [30].
v. MP and WHS are widely collected from the wild and destructive harvesting practices coupled with the degradation of forests, agricultural expansion, grazing pressure and urbanisation all threaten the survival of MP and WHS [31-35].

Further, climate change is predicted to have an even greater impact on diversity. Average temperatures are predicted to rise by 2–4°C over the next 50 years and cause considerable disturbance to regional and seasonal patterns of precipitation [1]. Climate acts directly on growth and reproduction of plant species [36] through physiological constraints and/or indirectly through ecological factors such as competition for resources [37], so changes in climate would inevitably affect species' survival. Several studies have already reported significant effects of climatic change over ecosystems and species [22-23]. Fischlin*et al.*predicted that by 2100, 10–30% of species globally were likely to go extinct as a result of climate change [38]. Negative effects of climate change included loss, expansion, relocation and fragmentation of habitats, and changes in distribution, abundance, phenology and physiology of a wide range of species [39-40, 25], as well as disruption of biotic interactions [39].

Thuiller*et al.* modelled the impact of different climate change scenarios on the distribution of 1350 plant species and concluded that more than half of the species were

predicted to become threatened with extinction by 2080 if they were unable to disperse [24]. On the other hand, plant taxa have the ability to respond to climatic changes, as happened during the quaternary when there were large-scale distribution shifts, so it was expected that they still maintained the ability to do so. Further he predicted that if taxa are able to adapt through migration, then about 22% would become critically endangered and 2% extinct. Additionally, some studies have reported a shift in species distribution towards the poles or upwards in altitude with gradual earlier seasonal migrations and breeding [22-23, 26]. Specifically, for CWR, a comparative study of the likely impact on three crop gene pools found 16–22% of CWR species would go extinct by 2055 and the majority of species showed greater than 50% loss of distributional range and the range that remained was highly fragmented [25].

Mitigation of effects of climate change

The Sultanate of Oman as represented by the stakeholders involved has undertaken several efforts to mitigate the effects of climate change on agriculture and plant genetic resources, which are as under:

The Sultanate of Oman had the National Biodiversity Strategy and Action Plan which had been done 2001 as a response to the Oman ratifying country of convention of biological biodiversity (CBD) in 1994 [41]. This strategy proposed a series of priority actions that were needed in achieving the main goals [42].After the establishment of the Ministry of Environment and Climate Affairs (MECA) in 2007, it has been leading with regard to dealing with various issues related to climate change [42].

MECA and other Ministries and organizations have carried out rapid assessment and initiated a preliminary study on the identification of climate change impact which indicated that the Sultanate of Oman was likely to be affected by climate changes which have been supported by the reports of the intergovernmental Panel on Climate Change (IPCC).

The following additional efforts have been made by MECA as mitigation measures in the Sultanate of Oman [42]. i). inclusion of climate changes issues in the scope of the work of the Environmental Impact Assessment (EIA) studies for the larger projects in the Sultanate of Oman since the year 2007 and development of the guidelines to carry out the climate change study as Form No 1. The main objective of the inclusion of climate change issued to EIA studies was to identify climate change vulnerabilities over the project and their adopted measures along with the mitigation measures which were implemented by the project; ii). Carrying out a regular Environmental Inspection Programs to the relevant projects in the Sultanate of Oman to confirm the project compliance with the Environmental Conditions stipulated in the Environmental Permits; iii). Inclusion of greenhouse gases (GHG) reporting and climate change issues into Monthly/ Quarterly Environmental Monitoring Reports submitted to the Ministry of Environment and Climate Affairs (MECA). The Directorate General of Climate Affairs has developed a specific reporting format which includes the several issues on industry's planning & efforts on energy auditing, energy efficiency, exploration of CDM opportunities, GHG emission reporting including GHG sinks. The data collected are used to update & develop the country policy & strategies on the concerned Environmental issues; iv). Development of a general environmental policy to encourage the relevant sectors in the Sultanate of Oman particularly the industrial sector to save energy consumption, improve energy efficiency and explore the possibility to adopt projects on renewable energy through Environmental Permitting System and CDM projects; v). Issuing the regulation for the approval of Clean Development Mechanism (CDM) Project under the Kyoto Protocol by the Ministerial Decision No. (30/2010) and vi). Updating the Regulation for the Control and Management of Ozone Depleting Substance (ODS) in 2005 in collaboration with United Nation Environment Programmed (UNEP); and establishment of the Designated National Authority (CDM-DNA) to promote the CDM Projects in the Sultanate of Oman by issuing the Ministerial Decision No. (30/ 2010) on regulations for the approval of clean mechanism (CDM) projects under the Kyoto Protocol. Subsequently, new opportunities for the development of renewable energy efficiency including climate change projects have been unlocked in the country.

Awareness of Climate Change

The MECA has established a program for awareness on climate change including- promoting environmental friendly attitudes and tendencies, addressing negative attitudes and habits towards environment and public health, encouragement of efforts and trends towards preserving the environmental and natural resources, concentrating on the role of the family, schools, social and activities and related establishments in the concern; organizing awareness seminars & workshops among the industry and public; A quarterly bilingual magazine named "Man & Environment" which include issues on environment, climate change, municipal and water resources.The country as represented by MECA developed an integrated development strategy to concerted Socio-economic aspects, protection of the environment and conservation of its natural resources for sustainable development.

Ratification & Adoption of Climate Change Related Convention

The Sultanate of Oman has actively participated in many international conventions and agreements related to the environment to environment Ratified and Adaption of Climate change related convention such as: - The UN Framework Convention on Climate Change (UNFCCC), The Kyoto Protocol of the United Nations Framework Convention on Climate Change, The Vienna Convention on the protection of Ozone Layer; and The Montreal Protocol on Ozone Depleting substances and its amendments at London, Copenhagen, Montreal and Beijing. MECA also, established National Policies/ Development Plans.

Ministries and other institutions involved working in Climate Change issues

Ministry of Agriculture and Fisheries (MAF):

MAF has been included for communication with MECA in terms of consultation on matters pertaining to permitting on use of certain species particularly the endangered ones. In this respect the MAF is working hard in the same line and different directions to which world trying to prevent or mitigate the effect of Climate Change. In Agriculture the ministry is working in several aspects to adapt new varieties of different crops in coping with climate change. MAF developed plan or strategy in collaboration with stockholder to reach the most effective solution for working with climate change viz: strategy for salinity, control desertification, development of resistant varieties against pests and diseases and also it has established 29 Ex-situ genebanks in different governorates in Oman for plant genetics resources [16] (Table 3).

Ministry of Municipality and Water Resources (MRMWR):

undertakes execution of several programs/projects regarding water resources, municipalities and climate change.

Oman Botanic Garden (OBG):

OBG is under the supervision of Royal Court and targets to complete the check list of plans of Oman

The Oman Animal & Plant Genetic Resources Center (OAPGRC):

the OAPGRC was established by The Research Council in 2012, with the Mission: to promote the recognition, sustainable utilization and valuation of the genetic diversity inherent in Oman's animal, plants and microorganism as a natural heritage resources.

Environmental Society of Oman (ESO):

founded in 2004, it is the sole Omani NGO that supports the government campaign for environment conservation and protection on national scale.

Diwan of Royal Court:

The Diwan of Royal court which handles similar environment projects is occasionally consulting MECA on biodiversity matters.

The Office for conservation of the Environment (OCE):

OCE is one sector at the Diwan of Royal court.

Sultan Qaboos University and Ministry of Heritage and Culture:

SQU and the Ministry of Heritage and Culture both keep scientific specimens and a limited number oflive plant collections. MECA has close working relationship with these agencies in terms of research and formulation of national policies on the conservation of the country's biodiversity. Housed in the Ministry of Heritage and Culture is the National Herbarium where 14,000 plus collections of plant specimens from over 1000 species of plants are kept in their herbarium together

Ministry of Education and Ministry of Higher Education:

In cooperation with MECA, the Ministry of Education took the lead in incorporating messages of biodiverse conservation in the curriculum of schools (Grades 1-12) with many schools participating in various environmental awareness programs of the government

Ministry of Information and Ministry of Tourism:

Oman's unique wildlife and nature reserves are key attractions of the country and as such are being featured and promoted by both the Ministries.

IV. Conclusion and Recommendations

The Sultanate of Oman is vulnerable to climate change because the increased average of temperature and fluctuating of rainfall with rising sea level and desertification. The agriculture and other food security related sector with plant genetic resources are under increasing pressure due to climate change, for instance, water, which is already scarce in the country has come under considerable stress, salinity, desertification, range lands and other plant genetic resources are degrading at an alarming rate as a result of climate change. Also increasing population, urbanization and other factors are playing significant roles and interact with climate change and environment. In view of the above, it was recommended to develop of the research program, to mitigate the effects of climate change through a team works include all stakeholder in Oman and to protectthe biodiversity through increasing the number of genes banks (Ex-situ and In-situ) giving great importance to crop wild relative (CRW). The changing climate is likely to increase the importance of the use of CWR in breeding new varieties to meet the futureneeds of farmers and the population. Attention should be given to improve and use the natural resources particularly water and genetic resources in sustainably, assess the impact of climate change in the environment and food security and develop a new crop variety as well as underutilized crops that can adapt to Omani environment and can cope with climate change.

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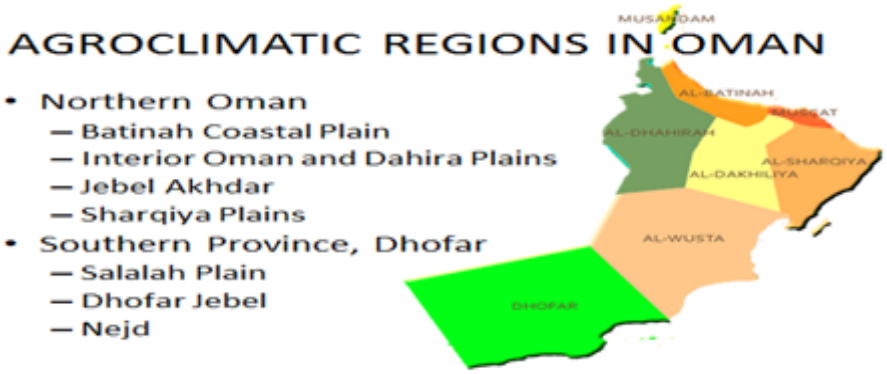

Fig.1. Agro-climatic regions of Oman

Table 1. Crop areas (ha) and production (tons) by crop group gown in Oman in 2013

Crop Group	Production (1000 ton)	Area (1000 ha)
Vegetables	314	11585.29
Fruits	398	30858.4
Field Crops	28	5603.78
Fodder crops	746	20483.19
Total	**1486**	**68590.67**

Table 2. Checklists of cultivated and wild socioeconomic plant resources of Oman

Use category	Family	Genera	Species	Data available
Crops	33	83	109	-
Crop landraces	21	38	43	1,404
Crop wild relative	78	251	708	2,721
Medicinal plant	95	283	448	1,481
Forestry	36	58	184	-
Ornamental	49	75	285	-
Combined socioeconomic plants	111	397	995	-

Table 3. Number of *Ex-Situ* genebanks in the Sultanate of Oman

Crop	Number of genebanks
Date palm	9
Banana	2
Citrus	8
Mango	5
Coconut	1
Guava	1
Deciduous Trees	3
Trees, shrubs and pastoral plants	1
The national seed gene bank	1
The medicinal plants	1