EXECUTIVE SUMMARY

This country report has not been produced through a participatory process involving several national stakeholders due to paucity of time. It has relied on important national documents submitted to FAO which are relevant to biodiversity in general and plant genetic resources for food and agriculture (PGRFA) and animal genetic resources (AnGR) in particular. The relevant literature on forests and aquaculture and fisheries was found limited. The report addresses and discusses with available literature relevant aspects concerning, *inter alia*, the role, drivers of change, state, trends and use of biodiversity for food and agriculture besides state of interventions and future agendas/ needs on conservation and sustainable use of biodiversity for food and agriculture.

The Sultanate embraces diverse agro-climatic regions and the principal occupations of the population are agriculture and fishing. It is very well perceived that from the point of long-term national economy and food security, diversification of the agricultural production and sustainable utilization of existing resources are a necessity.

Oman has a wide diversity of animal breeds of sheep, goats, cattle and camel and 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 breeds of both small and large ruminants besides poultry but it has also diverse cultivars and land races of crop species and unexplored wild relatives of some crop plants as well as wild foods in the forest areas which can be explored for use. There are evidences of an increasing pressure on this diversity from several factors or drivers of change, 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 species and cultivars in its rich biodiversity. Similar situation exists with respect to aquaculture and fisheries. 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.

Oman has a satisfactory knowledge on the state and trends of production and associated biodiversity due to its association with CBD to develop its own national biodiversity strategy and action plan (NABSAP) as early in 1990s. Trends in many species and communities of biodiversity are documented and monitored, and new research programmes have been initiated to fill key gaps by the relevant stakeholders especially on the topics of climate change, invasive species, wild crop relatives, marine environments and forest species for food. However, we lack sufficient scientific data as evidence about drivers of changes in the components of biodiversity discussed viz. livestock, forests, aquaculture and fisheries, and crops. Information on other ecosystem services was found insufficient to discuss about trends and drivers in relation to biodiversity components. The available information on state, trends, use and future needs of four components of biodiversity for food and agriculture were presented and discussed.

CHAPTER 1

Introduction to the Sultanate of Oman and to the Role of Biodiversity for Food and Agriculture

Preparation of the Report

Sultanate of Oman has several stakeholders are working directly or indirectly on the four components of the biodiversity for food and agriculture addressed in this report. These are Ministry of Agriculture & Fisheries (MAF), Ministry of Environment and Climate Affairs (MECA), Ministry of Heritage and Culture (MHC), Diwan of Royal Court (DRC), Royal court Affairs (RCA), The Sultan Qaboos University (SQU) and Oman Animal & Plant Genetic Resources Center (OAPGRC) of The Research Council (TRC). The process of preparation of this report did not adhere to the systematic process with stakeholders suggested by FAO due to paucity of time for its submission. We relied upon the recent stakeholder process for preparing the Vth National report to CBD (Convention of Biological Diversity) by the Ministry of Environment and Climate Affairs, which covered biodiversity for agriculture and food besides terrestrial and marine flora and population. We also referred to the heavily from the Strategy and the Fifth National Report to the Convention on Biological Diversity (2014). We also referred extensively to the national reports on the State of Plant Genetic Resources for Food and Agriculture and the State of Animal Genetic Resources in Oman submitted to FAO by the Ministry of Agriculture & Fisheries. We compiled the information from the key reports and to access the most up-to-date information and additionally reviewed relevant literature and interviewed a number of stakeholders and experts in different livestock, forests, aquaculture and fisheries and crops (Annex 1). The questions dealing with gaps and priorities, specific management challenges and priorities, and planned actions were merely answered from the information in above reports based on the guidelines for the preparation of country report for *The State of World's Biodiversity for Food and Agriculture*.

Introduction to the Country

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′ and 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 (Figure 1) with islands and islets to the mountain range that culminates 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' El Khali (Empty Quarter) covering the southwest of Oman, and *wadis* (dry riverbeds). Oman borders on its north side the Strait of Hormuz and the United Arab Emirates, on the northwest Saudi Arabia while at the southwest the Republic of Yemen. As of 1 January 2015, the population of Oman was estimated to be 3 519 120 people.

Figure 1. Location of the Sultanate of Oman

Ecosystem/Species Biodiversity of Oman

The land of Oman is formed from stony desert plains, sandy and mountainous areas as well as littoral and coastal plain. The latter covers 3% of Oman surface Area (Ref: National Strategy of sustainable development for animal resources [NSSDAR]). Despite its dry climate, Oman is located in an area of outstanding biodiversity, mainly in the parts of the Sultanate where the precipitation is the highest.

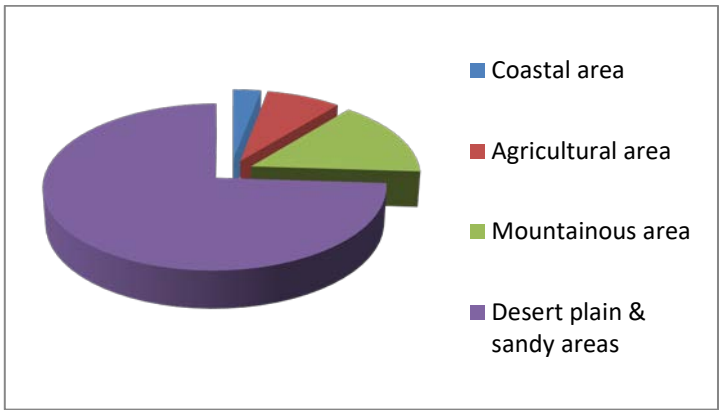

Figure 2. Percentage of the main recognized ecosystems in Oman. *Source NSSDAR, 2012*.

The habitats of Oman are of a wide variety and range from coastal plains, rivers, lagoons, Khwars, Sebkhas, and deserts to mountains, whereas the main recognized ecosystems are presented in Figure 2.

Desert (74% of Oman) Biodiversity:

Sand dunes and gravel deserts (Seih) cover a great proportion of the land surface of Oman. These areas are generally hyper arid with less than 100 mm of rainfall per year. They have mosaic of little vegetation mostly confined to depressions, wadis, runnels and rocky pavements. These areas are treeless with very few species. The principal vegetation in the rocky and gravel desert include *Acacia - Prosopis – Ziziphus* woodland with shrubs like *Lycium shawii* and *Ochradenus arabicus*. Common annual vegetation includes *Zygophyllum simplex, Plantago ovata, Aizoon canariense* and *Asphodelus fistulosus.* The Sand dunes have two main plant communities: 1) *Calligonium critinum arabicum* and*Cyperus eremecius* and 2) *Heliotropium, Panicum, Euphorbia* and *Indigofera*.

Vegetation is scattered with *Bosellia sacra* tree and *Acacia etbaica*bushes predominate. Larger areas of the desert are deprived from vegetation. The succulent *Zygophyllumqatarense* and the leguminous tree *Prosopis cineraria* are the ones that also dominate the landscape. Near the edge of the desert, some common vegetation persist: *Calligoniumcrinitum,Tribulus arabicus, Dipterygium glaucum, Cyperus conglomerates, Heliotropium kotschyii* and *Zygophyllum qatarense.* Restricted to the central desert plains and hinterland include *Pristurus minimus,Uromastyx thomasi* and *Acanthodactylus masirae.*

Mountain (15% of Oman Biodiversity:

There are two categories of recognized mountain biodiversity in Oman: arid and monsoon-affected mountains. Hajar mountains in northern Oman including Musandam peninsula are dry with bare rock outcrop and varied shallow soils dominating on sloping terrain and with very gravelly soils occurring in the valleys and alluvial fans. Many scattered oases abound with mostly falaj irrigation systems, tap local springs or wadis underflow where date palms, limes, banana, alfalfa and vegetables grow. Remnants of forests, dense woodland and related plant formations are restricted to the mountainous regions of Oman. Two types of mountains predominate in the country: dry in the larger part and semitropical in the Dhofar region. Montane vegetation exhibits a distinct latitudinal zonation. The alluvial wadi fans and foothills of the mountains are dominated by open, drought-decidous woodlands and shrub lands, often intermixed with xeromorphic grasslands, *Panicum turgidum* community dominated by *Acacia ehrenbergiana, A. tortilis, Prosopis cinerea* and *Ziziphusspina-christi* (NSSDAR, 2012).

In the central range of the westen Hajar mountains, from 2100 m to the summit at 3000 m, isolated populations of *Juniperus excelsapolycarpos* form open woodland, often dominant with *Olea europaea*. Juniper trees are generally in a poor state and regeneration is minimal. At lower elevation, the trees are in very poor condition and regeneration is virtually absent. The juniper woodlands of Oman are unique to the Arabian Peninsula and they may be a result of plant migrations from SE Iran across the Arabian Gulf.

Northern Oman Mountains passing through the eastern UAE are definitely a center of endemism. Three nationally endemic species namely *Asaacus montanus, Asaccus platyrhynchus* and *Pristurus gallagheri* and five regionally endemics such as *Asaccus caudivolvulus, Asaccus gallagheri, Pristurus celerrimus, Lacerta jayakari* and *Lacertacyanura.* The Dhofar Mountains until Yemen also contain a number of endemic species: *Hemidactylus lemurinus, Meslaina ayunensis* and *Coluber thomasi*.

Moisture rich mountains occur in Dhofar Region along north of Salalah and Rakhyout coast. Woody vegetation predominates on steep slopes and gullies while grass and bushes under heavy grazing cover most of the plains. Soils are generally shallow in the grazed areas which mean that soil erosion is rampant in the rangelands. Wooded slopes are protected from erosion by trees and bushes and they

generally have deep soils. Rain-fed cultivation of beans and sorghum is done by some Jibali in very tiny plots during the monsoon.

Agricultural (8% of Oman surface area) biodiversity:
Soil survey of MAF in 2004-2005 revealed that 2.223 million hectares are suitable for agricultural activities (7.4% of the surface area of the country). Another peculiarity of Oman is found in its food culture and legacies; in this respect more and more people is involved in agricultural and farming activities to contribute to the productive system. The distribution of holdings over the Governorates is given in Table 1 (MAF, 2014).

Table 1. Number of holdings distributed by type of holding in different governorates

Governorate	%	Total	Crops Livestock & Poultry	Livestock & Poultry	Crops & Poultry	Crops & Livestock	Poultry	Livestock	Crops
Muscat	5.09	8478	257	75	59	1105	16	1892	5074
Dhofar	8.25	13750	43	6	9	1097	3	10488	2104
Musandam	2.40	4003	101	30	9	784	2	1084	1993
Buraimi	2.72	4508	235	158	26	862	9	554	2664
Dakhiliya	19.26	32090	783	128	194	5222	34	4144	21585
Batinah N	13.37	23942	1212	543	74	6533	63	6659	8858
Batinah S	12.36	20569	636	60	101	3350	15	2903	13531
Sharkiyah S	9.37	15610	138	244	23	1296	23	8766	5120
Sharqiyah N	15.18	25283	447	161	77	2740	23	5921	15914
Ghahirah	9.49	15812	490	157	63	3702	19	2464	8917
Wusta	1.52	2531	0	1	0	26	0	2458	46
Total	100	166603	4342	1563	635	26717	207	47333	85806
Percentage		100	2.61	0.94	0.38	16.04	0.12	28.41	51.50

New ways to produce food is now furthering the sustainability of the production itself, dimming the impact on the environment, supplying better quality food, and last but not least, improving life condition for farmed animals. Furthermore traditional agriculture and farming activities normally avoid using large areas for monoculture, allowing the persistence of marginal areas and eco-tones, enhancing preservation of biodiversity, and providing necessary connection between areas serving as dispersal corridors. Sound farming practices especially on water conservation techniques, arresting soil erosion and the use of safe pesticides and chemical fertilizers have been addressed in the agriculture sector. Gene banks for leading crops, pasture and grass species were established for safe keeping and posterity.

Livestock Biodiversity
In Oman animal genetic resources vary from one governorate to another. Animal genetic resources in Oman are consisted of cattle, camels, sheep, goats, poultry, horses, mules and asses. Cattle represent about 74% in Dhofar, 12% in Al-Batinah, 4% each in Zahra, Interior and Eastern Regions while the rest in the other regions. Prevailing cattle production system is moderate input. Camels which represent 71% in Dhofar, 9% in Eastern Region, 7% in the Middle Region, 6% in Zahra, about 4% in Al-Batinah and 3% in the Interior. Camels are mainly raised under low-input system. Sheep population distributed as 31% in Al-Batinah, 22% in Eastern Region, 20% in Zahra, 13% in the interior area, 5% in Muscat, 4% in the Middle, 3% in Musandam and 2% in Dhofar. Sheep are mostly produced under nomadic or semi-nomadic (transhumant) system with moderate input. Goats represent 23% in Al-Batinah, 19% in the Eastern Region, 17% in Dhofar, 15% in Zahra,9% in the Interior, 8% in the Middle Region, 7% in Musandam and 2% in Muscat. Goats are raised mostly under nomadic

and transhumant system with moderate inputs. Statistics for poultry are from commercial flocks, which are exclusively dependent on exotic stocks while statistics on local poultry are inaccurate. The Sultanate has also a modest population of horses, asses and mules but there are no dependable statistics regarding them (MAF, 2012).

The livestock sector is managed by the private sector supported by the State through extension services and investment facilitation. Livestock production units are characterized by their small size and an absence of administrative organization. There are promising specialized commercial dairy and poultry farms but their numbers are still limited. Recently there have been trends of accelerating growth in broiler and egg production due to the high return on the investment, availability of investment facilities and the planning and supervision. Other livestock activities are stable (MAF, 2012).

The Sultanate took significant steps to realize food security through enhancing domestic agricultural production which helped the increase in the self-sufficiency rate in some products like milk and table eggs. However, self-sufficiency rate is still low in some other products like red meat and poultry meat. Despite this low self-sufficient rate, the Sultanate does not suffer from lack of food due to its economic ability to import its needs under free market conditions beside surplus in other items like dates and fish. Demand on animal products has increased lately especially on red meat, poultry meat, eggs and milk as evidenced by statistics on the imports of these products. Significant changes have also taken place in the agricultural production systems towards intensification, where there is large increase in high-input production systems in poultry and dairy cattle due to the increase in demand, high economic returns and the investment facilities. There has also been a concomitant increase in attempts to increase local feed production but lack of water resources has proven to be a great obstacle to achieve this.

Due to the particular environmental factors of the Sultanate, mainly shortage of water for irrigation and the high temperature and humidity, it is not expected to meet the demand on animal products in the future by increasing the number of animals but it is promising to meet such increasing demand on animal products by improving productivity through genetic improvement of local breeds and expanding specialized– production projects.

After the preparation of the country report on the state of Oman's Animal genetic resources in 2012, the Ministry of Agriculture and Fisheries started a program on how to utilize and conserve animal genetic resources in line with the basic elements and the steps used and developed by the Food and Agriculture Organization (FAO) of the United Nations.

Forest Biodiversity

Wadis, khwars, sabkhas and mangrove forests encompass the country's wetlands.

Seasonal water flows or *wadis* are one of the most common and important landscape elements in Oman draining rainwater from wide catchment areas and high mountains.

Terraces along *wadi* banks are intensively farmed. Vegetation along *wadis* include *Tamarix, Saccharum sp., Nerium mascatense, Ficus cordata* and *Acacia nilotica*. Alluvial plains support growth of *Acacia, Ziziphus, Moringa* and *Ficus salicifolia*. Extensive sand dunes are associated to the coastal areas and are important protector of beaches. The dunes and their associated grasses and shrubs trap

marine sands which help prevent both the erosion of beaches and the covering of inland areas by wind-blown sand (.

Coastal plains and *sabkha* vegetation are dominated by communities of halophytes, drought-decidious thorn woodlands and open xeromorphic shrub lands and grasslands. There are four coastal vegetation communities recognized (Patzelt and Al Farsi, 2000; 4th NR to CBD, 2009): 1) *Limonium stocksii-Zygophylum quatarense* community in northern Oman where the coasts are mainly sandy and interspersed with rocky limestone, 2*) Limonium cf. stocksii-Suaeda aegyptica* community characteristic or rocky shores with narrow beach areas and a wide spray zone, 3*) Atriplex-Sueda* community along offshore islands, flat sandy beaches and coastal sabkhas, 4) coastal lagoons with *Sporobolus virginicus, Sporobolus iocladus* and *Paspalum vaginatum*as bordering species and *Phragmites australis* and *Typha spp* forming bordering reeds. Oman has a coastline stretch of 3,165 km which had been perceived as entirely covered by mangroves long time ago. Unfortunately, mangroves had been greatly reduced due to deforestation for fuel wood, grazing, and coastal developments. Mangrove vegetation is spread sporadically in the coastal areas of the country. In spite of massive mangrove destruction, there still exist good stands in Northern Batinah, Muscat, Eastern Sharqiyah, Mahawt Island and Salalah. It now covers a total of 1000ha (2010 International Year of Biodiversity Oman Report). There are few outstanding islands in Oman which include Dimaniyat, Masirah and Kuria- Murai (Hallniyat). Except for Dimaniyat, all other islands are still in the proposal state to become protected areas. Forests and woods are chiefly found in the coastal (mainly mangrove) and mountainous areas of the country where the forests cover 20 km^2 and the woods 13000 km^2. The species diversity and the affinities of three main contrasting ecosystems of the country are given in the Table 2.

Table 2. Three main contrasting ecosystems with their species and affinities in Oman

Ecosystem	Affinity	Endemism	Species diversity
Desert	Irano-Pakistanian		*Desert to Arid: Acacia-Prosopis-Ziziphus* woodlands with shrubs like *Lycium ,Ochradenus*. Common annual vegetation include *Zygophyllum, Plantago, Aizoon* and *Asphodelus fistulosus,Calligonium, Cyperus, Heliotropium, Panicum, Euphorbia,* and *Indigofera*. Fauna restricted to central desert plains: *Pristurusminimus,Uromastyxthomasi*and*Acanthodactylusmasirae*
Hajar Arid Mountain	Irano-Pakistanian	7 species	Foot hills: dry with bare rock outcrop and scattered *Acacia-Prosopis-Ziziphus.* *Central western Hajar with Juniperus excels polycarpos*
Monsoon affected Mountain	African Semi-tropical	4 species	Humid in summer with monsoon rain and relatively dense woods

The centers of endemism and the services of the ecosystems through conservation and regulation of the environment are considered highly appreciated by the people of Oman. The centers of plant endemism are the mountains of northern Oman, the central desert and the mountains of Dhofar (Patzelt, *in press*).

Protected areas (PAs) now cover 9.64.3% of Oman territory. These are distributed over various ecosystems/habitats and two main eco-regions/bio-geographical regions. The previous percentage

(13.8%) that was provided by "Earth Trends country profile, 2003" and later by "World Bank, 2013" is due to considering the Oman surface area 212246 km^2 instead of 309500 km^2. One of the preoccupations of the future PAs Strategy of Oman is the delimitation of the boundaries of the protected areas so that the correct data can be used as an indicator for assessment and evaluation and as a benchmark for future monitoring.

Aquaculture & Fisheries Biodiversity

Khwars are productive and valuable fish-breeding and nursery areas supporting dense masses of *Enteromorpha*, mullet fishes and the edible crab *Scylla serrata*.

Both the islands and the reefs are important to the mainland-based fishermen and people from Muscat, for fishing, recreation and worship. This is the most important site for wildlife conservation in the capital area and urgently in need of a management plan. Surveys conducted in the preparation of the Oman Coral Reef Management Plan have revealed significant damage to the reefs and widespread degradation. The coral reefs are threatened by large scale, irreversible damage and continued devaluation or loss of coral reef resources.

The reserve is an outstanding conservation area of national and regional importance. They have the highest density of nesting seabirds and the only known osprey nesting sites in the capital area. They also shelter the largest nesting population of hawksbill turtles in the country. These are relative unspoiled islands of great scenic beauty offering a living natural museum, including the nesting green turtles and sooty falcons and a variety of reefs with high coral diversity.

Crops Biodiversity

Irrigated land area is about 72,820 ha and planted with various crops. Table 3 below shows estimates of cultivated areas in 2004 (MAF, 2004-05).

Table 3. Estimates of cultivated areas (1000ha) and production (1000T) for various agricultural crops in 2004in Oman

Agricultural crops	Area	Production
Vegetables	6.65	162
Fruits	42.04	329.2
Field crops	6.25	24.8
Perennial fodder crops	17.88	728.8
Total	**72.82**	

Agricultural lands are highly dependent on fertile lands which are likely located along the coastal plain, at Batina and Salala and wadi banks of the mountainous area. Among Oman's top plantation crops raised by irrigation system would include the following: figs, guava, jujube, papaya, lemon, mango and dates. Locally produced crops such as pomegranate, banana, lettuce are locally consumed but many other crops are imported to supply the local markets. Other fruits, vegetables, grain crops and fodder are produced in Oman. Native plants are also produced into handicrafts, medicines and household items. Fisheries provide significant direct economic benefits whereas the agricultural sector in general represents -6% to 14.6 in 2008 of GDP and ranks first among the non-oil exports (NSSDAR, 2012).

Very large numbers of small farm holdings (about one hectare each) are cultivated to low yielding varieties, under fertilized and over-irrigated traditional crops. Soil fertility is expected to deteriorate

after successive cultivation following single or double crop rotation system. Rate of mineral fertilizers applied is very low worsening the situation of soil fertility. Organic fertilizers are least practiced in Oman. Larger numbers of cattle, sheep, goats and camels went beyond the carrying capacities of the rangeland grazing. This caused the deterioration of vegetation composition and biomass productivity. Desertification had encroached on Dhofarmountains due to: heavy over stocking, little application of rangeland management practices and significant deterioration in rangeland and productivity.

Human Population and Trends

The current estimated population of Oman is 3.295 million in 2011 including 2.013 million Omanis and 1.282 expatriates according to Statistical Year Book 2012 with a growth rate of 2.04 % according to CIA World Fact book published in 2013. Population density is greatest in Muscat (30.46 %) followed by Al Batinah (24.83 %); 28.4% of the population lives in vast rural areas and nearly 5% lives in mountains and other hilly areas according to World Bank report published in 2011. About one-third of the population is related to agriculture (MAF, 2005). Income, education, and health indices have widely increased as compared to the past decade reflecting a balanced progress across the different governorates with almost equal improvement in life expectancy and education for men and women.

Production Systems

Agricultural land accounts for roughly 7 percent of the total land in Oman, equivalent to about 5.3 million feddans. Of these, only 1.9 million feddans are classified as highly suitable while 3.4 million feddans are marginally suitable. Moreover, only about 10 percent of the suitable land is cultivated, 50 percent of which is located in the coastal areas of Al-Batinah (North) and Salalah plain in Dhofar Governorate. A dual farming system, that includes crops, annual forage and livestock like sheep, goats and cattle, of small subsistence family farms co-existing with large commercial farms characterize the agricultural production. According to the 2012/13 agricultural census (MAF, 2014), 89 percent of farms are less than 5feddans where farmers mainly grow alfalfa and annual grasses as forage for their livestock and vegetables in either open field or plastic houses and occupy 24.6 percent of the total arable land. Furthermore, 72 percent of all farms account for less than 1feddan where both forage and crops are grown along with few livestock animals like sheep and goats but occupy only 7 percent of the total arable land. Small farms dominate the farming systems and produce more than 63 percent of total fruits and vegetables. A significant proportion of small holdings are operated by part-time farmers for whom farming is not the main source of income, yet small farms achieve higher gross margin per unit of land than large farms (OSS, 2012).

Agriculture remains the main livelihood source for the 800 000 Omanis who make up the rural population – accounting for slightly less than 30 percent of the total population. The main production systems identified in Oman are presented in Table 4 while their description is provided in Table 5. Mixed production system in Oman mainly include crops, forage and livestock while in negligible area we find mixed production system involving fish culture. The data on area in respect of various production systems and their contribution to economy are not available.

Table 4. Production systems identified in Oman

Sector	Code	Production system names	Present (Y/N)
Livestock	L1	Livestock grassland-based systems: Tropics6	Y
	L2	Livestock grassland-based systems: Subtropics7	Y
	L3	Livestock grassland-based systems: Temperate8	Y
	L4	Livestock grassland-based systems: Boreal and /or highlands9	N
	L5	Livestock landless systems: Tropics	Y
	L6	Livestock landless systems: Subtropics	Y
	L7	Livestock landless systems: Temperate	Y
	L8	Livestock landless systems: Boreal and /or highlands	N
	F1	Naturally regenerated forests: Tropics	Y
	F2	Naturally regenerated forests: Subtropics	Y
	F3	Naturally regenerated forests: Temperate	Y
	F4	Naturally regenerated forests: Boreal and /or highlands	N
	F5	Planted forests: Tropics	N.A.
	F6	Planted forests: Subtropics	N.A.
	F7	Planted forests: Temperate	N.A.
	F8	Planted forests: Boreal and /or highlands	N
	A1	Self-recruiting capture fisheries: Tropics	Y
	A2	Self-recruiting capture fisheries: Subtropics	Y
	A3	Self-recruiting capture fisheries: Temperate	Y
	A4	Self-recruiting capture fisheries: Boreal and /or highlands	N
	A5	Culture-based fisheries: Tropics	Y
	A6	Culture-based fisheries: Subtropics	Y
	A7	Culture-based fisheries: Temperate	Y
	A8	Culture-based fisheries: Boreal and /or highlands	N
	A9	Fed aquaculture: Tropics	Y
	A10	Fed aquaculture: Subtropics	Y
	A11	Fed aquaculture: Temperate	Y
	A12	Fed aquaculture: Boreal and /or highlands	N
	A13	Non-fed aquaculture: Tropics	NK
	A14	Non-fed aquaculture: Subtropics	NK
	A15	Non-fed aquaculture: Temperate	NK
	A16	Non-fed aquaculture: Boreal and /or highlands	NK
	C1	Irrigated crops (rice) : Tropics	N
	C2	Irrigated crops (rice) : Subtropics	N
	C3	Irrigated crops (rice) : Temperate	N
	C4	Irrigated crops (rice) : Boreal and /or highlands	N
	C5	Irrigated crops (other) : Tropics	Y
	C6	Irrigated crops (other) : Subtropics	Y
	C7	Irrigated crops (other) : Temperate	Y
	C8	Irrigated crops (other) : Boreal and /or highlands	N
	C9	Rainfed crops : Tropics	N
	C10	Rainfed crops : Subtropics	N
	C11	Rainfed crops : Temperate	N
	C12	Rainfed crops : Boreal and /or highlands	N
	M1	Mixed systems (livestock, crop, forest and /or aquatic and fisheries): Tropics	N
	M2	Mixed systems (livestock, crop, forest and /or aquatic and fisheries): Subtropics	N
	M3	Mixed systems (livestock, crop, forest and /or aquatic and fisheries): Temperate	N
	M4	Mixed systems (livestock, crop, forest and /or aquatic and fisheries): Boreal and /or highlands	N
	O1	Others [please specify]	N

6 Tropics: All months with monthly mean temperature, corrected to sea level, above 18°C. ; 7 Subtropics: One or more months with monthly mean temperatures, corrected to sea level, below 18°C but above 5 °C. ; 8 Temperate: At least one month with monthly mean temperatures, corrected to sea level, below 5 °C and four or more months above 10 °C.; 9 Boreal and/or highlands: At least one month with monthly mean temperatures, corrected to sea level, below 5 °C and more than one but less than four months above 10 °C. NK- No knowledge

Table 5. Production systems present in Oman

Sector	Code	Production system names	Present (Y/N)	Description
Livestock	L1	Livestock grassland-based systems: Tropics[6]	Y	Livestock grassland-based systems are present in mountains of Southern Dhofar governorate in large area ( ) whereas same also is present in North Oman spread over other governorates in both plains and mountains in their tropical and sub-tropical areas and temperate climate in mountains.
	L2	Livestock grassland-based systems: Subtropics[7]	Y	
	L3	Livestock grassland-based systems: Temperate[8]	Y	
	L5	Livestock landless systems: Tropics	Y	Livestock landless systems also exist in Oman but in negligible proportion
	L6	Livestock landless systems: Subtropics	Y	
	L7	Livestock landless systems: Temperate	Y	
Forests	F1	Naturally regenerated forests: Tropics	Y	Naturally regenerated forests are spread over all the governorates of Oman not only plains but also in mountains.
	F2	Naturally regenerated forests: Subtropics	Y	
	F3	Naturally regenerated forests: Temperate	Y	
Aquaculture and Fisheries	A1	Self-recruiting capture fisheries: Tropics	Y	Includes capture fisheries in marine, coastal and inland areas that can involve: Natural ecosystems and Modified ecosystems e.g. reservoirs
	A2	Self-recruiting capture fisheries: Subtropics	Y	
	A3	Self-recruiting capture fisheries: Temperate	N	
	A4	Self-recruiting capture fisheries: Boreal and /or highlands	N	
	A5	Culture-based fisheries: Tropics		Fisheries on resources, the recruitment of which originates or is supplemented from cultured stocks raising total production beyond the level sustainable through natural processes.
	A6	Culture-based fisheries: Subtropics		
	A7	Culture-based fisheries: Temperate		
	A9	Fed aquaculture: Tropics		The farming of aquatic organisms including fish, mollusks, crustaceans, aquatic plants, crocodiles, alligators, turtles and amphibians. Farming implies some sort of intervention in the rearing process to enhance production,
	A10	Fed aquaculture: Subtropics		
	A11	Fed aquaculture: Temperate		
	A13	Non-fed aquaculture: Tropics		The farming of aquatic organisms including fish, mollusks, crustaceans, aquatic plants that do not need supplemental feeding. Farming implies some sort of intervention in the rearing process to enhance production.
	A14	Non-fed aquaculture: Subtropics		
	A15	Non-fed aquaculture: Temperate		
	C5	Irrigated crops(other) : Tropics	Y	All the food, fodder, horticulture (tree) and vegetable crops are grown as irrigated. No crops are grown as rain-fed. While food fodder and horticulture (tree) crops are grown under modern irrigations systems, vegetables are grown both in open-field and plastic houses and under hydroponics without soil.
	C6	Irrigated crops(other) : Subtropics	Y	
	C7	Irrigated crops(other) : Temperate	Y	
Mixed[10]	M1	Mixedsystems(livestock, crop, forest and /or aquatic and fisheries): Tropics	N	Mixed crop systems (livestock, crop, forest and /or aquatic and fisheries) are not available in Oman.
	M2	Mixed systems(livestock, crop, forestand /or aquatic and fisheries): Subtropics	N	
	M3	Mixed systems(livestock, crop, forest and /or aquatic and fisheries): Temperate	N	
	M4	Mixed systems(livestock, crop, forestand /or aquatic and fisheries): Boreal and /or highlands	N	

CHAPTER 2

Drivers of Change

Effects of drivers of change on biodiversity for food and agriculture and ecosystem services:

The effects of drivers of change in different sectors of biodiversity are presented in Tables 6 to 9 while that of ecosystem services are presented in Tables 10 to 13.

Table 6. Effect of drivers on Livestock biodiversity within production systems in the country, by animal (AnGR), plant (PGR), aquatic (AqGR) and forest (FGR) genetic resources.

Production systems	**Drivers14**	**Effect of drivers on sector biodiversity for food and agriculture** (2, 1, 0,-1, -2, NK, NA)			
Code or name		PGR	FGR	AnGR	AqGR
Livestock: (L1, L2, L3,, L4, L5 & L6)	Changes in land and water use and management	0	0	0	0
	Pollution and external inputs	1	NK	NK	1
	Over-exploitation and overharvesting	1	1	1	1
	Climate change	1	1	1	1
	Natural disasters	0	0	0	0
	Pests, diseases, alien invasive species	1	1	1	1
	Markets, trade and the private sector	0	0	0	0
	Policies	0	0	0	0
	Population growth and urbanization	1	1	1	1
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK

12 Description of drivers can be found in Annex 3. 13 Description of associated biodiversity can be found in Annex 1. 14 Description of drivers can be found in Annex 3; NK- No knowledge

Table 7. Effect of drivers on Forests biodiversity within production systems in the country, by animal (AnGR), plant (PGR), aquatic (AqGR) and forest (FGR) genetic resources.

Production systems	**Drivers14**	**Effect of drivers on sector biodiversity for food and agriculture** (2, 1, 0,-1, -2, NK, NA)			
Code or name		PGR	FGR	AnGR	AqGR
Forests: (F1, F2, F3)	Changes in land and water use and management	0	0	0	0
	Pollution and external inputs	1	NK	NK	1
	Over-exploitation and overharvesting	1	1	1	1
	Climate change	1	1	1	1
	Natural disasters	0	0	0	0
	Pests, diseases, alien invasive species	1	1	1	1
	Markets, trade and the private sector	0	0	0	0
	Policies	0	0	0	0
	Population growth and urbanization	0	0	0	0
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK
	Advancements and innovations in ~~science~~ and technology	NK	NK	NK	NK

12 Description of drivers can be found in Annex 3.13 Description of associated biodiversity can be found in Annex 1.
14 Description of drivers can be found in Annex 3. NK- No knowledge

Table 8. Effect of drivers on Aquaculture & Fisheries biodiversity within production systems in the country, by animal (AnGR), plant (PGR), aquatic (AqGR) and forest (FGR) genetic resources.

Production systems	**Drivers14**	**Effect of drivers on sector biodiversity for food and agriculture** (2, 1, 0,-1, -2, NK, NA)			
Code or name		PGR	FGR	AnGR	AqGR
Aquaculture & Fisheries: (A1, A2)	Changes in land and water use and management	0	0	0	0
	Pollution and external inputs	1	NK	NK	1
	Over-exploitation and overharvesting	1	1	1	1
	Climate change	1	1	1	1
	Natural disasters	0	0	0	0
	Pests, diseases, alien invasive species	1	1	1	1
	Markets, trade and the private sector	0	0	0	0
	Policies	0	0	0	0
	Population growth and urbanization	1	1	1	1
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK

12 Description of drivers can be found in Annex 3.
13 Description of associated biodiversity can be found in Annex 1. 14 Description of drivers can be found in Annex 3.
NK- No knowledge

Table 9. Effect of drivers on crops biodiversity within production systems in the country, by animal (AnGR), plant (PGR), aquatic (AqGR) and forest (FGR) genetic resources.

Production systems	**Drivers14**	**Effect of drivers on sector biodiversity for food and agriculture** (2, 1, 0,-1, -2, NK, NA)			
Code or name		PGR	FGR	AnGR	AqGR
Crops: (C5, C6 C7)	Changes in land and water use and management	1	NK	1	0
	Pollution and external inputs	1	NK	NK	1
	Over-exploitation and overharvesting	1	1	1	1
	Climate change	1	1	1	1
	Natural disasters	0	0	0	0
	Pests, diseases, alien invasive species	1	1	1	1
	Markets, trade and the private sector	0	0	0	0
	Policies	0	0	0	0
	Population growth and urbanization	1	1	1	1
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK

12 Description of drivers can be found in Annex 3.
13 Description of associated biodiversity can be found in Annex 1. 14 Description of drivers can be found in Annex 3.
NK- No knowledge

Table 10. Major drivers and their effect on ecosystem services in production systems related to livestock.

Production systems	**Drivers15**	**Effect of drivers on ecosystem services 16** (2, 1, 0,-1, -2, NK, NA)								
Code or name		Pollination	Pest and disease regulation	Water purification and waste treatment	Natural hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ Gas regulation
Livestock: (L1, L2, L3,, L4, L5 & L6)	Changes in land and water use and management	NK	1	NK	NK	NK	NK	NK	NK	NK
	Pollution and external inputs	NK	1	NK	NK	NK	NK	NK	NK	NK
	Over-exploitation and overharvesting	NK								
	Climate change	NK	1	NK	NK	NK	NK	NK	NK	NK
	Natural disasters	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Pests, diseases, alien invasive species	NK	1	NK	NK	NK	NK	NK	NK	NK
	Markets, trade and the private sector	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Policies	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Population growth and urbanization	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Other [*pleasespecify*]	NK	-	-	-	-	-	-	-	-

15 Description of drivers can be found in Annex 3.
16 Description of ecosystem services can be found in Annex 4.
NK- No knowledge

Table 11. Major drivers and their effect on ecosystem services in production systems related to forests.

Production systems	**Drivers15**	**Effect of drivers on ecosystem services 16** (2, 1, 0,-1, -2, NK, NA)								
Code or name		Pollination	Pest and disease regulation	Water purification and waste treatment	Natural hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ Gas regulation
Forests: (F1, F2, F3)	Changes in land and water use and management	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Pollution and external inputs	1	1	NK	NK	NK	NK	NK	NK	NK
	Over-exploitation and overharvesting	1	1	NK	NK	NK	NK	NK	NK	NK
	Climate change	1	1	NK	NK	NK	NK	NK	NK	NK
	Natural disasters									
	Pests, diseases, alien invasive species	1	1	NK	NK	NK	NK	NK	NK	NK
	Markets, trade and the private sector	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Policies	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Population growth and urbanization	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Other [*pleasespecify*]	-	-	-	-	-	-	-	-	-

15 Description of drivers can be found in Annex 3.
16 Description of ecosystem services can be found in Annex 4.
NK- No knowledge

Table 12. Major drivers and their effect on ecosystem services in production systems related to aquaculture & fisheries

Production systems	**Drivers15**	**Effect of drivers on ecosystem services 16** (2, 1, 0,-1, -2, NK, NA)								
Code or name		Pollination	Pest and disease regulation	Water purification and waste treatment	Natural hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ Gas regulation
Aquaculture & Fisheries: (A1, A2)	Changes in land and water use and management	1	1	NK	NK	NK	NK	NK	NK	NK
	Pollution and external inputs	1	1	NK	NK	NK	NK	1	NK	NK
	Over-exploitation and overharvesting	1	1	NK	NK	NK	NK	NK	NK	NK
	Climate change	1	1	NK	NK	NK	NK	NK	NK	NK
	Natural disasters	1	1	NK	NK	NK	NK	NK	NK	NK
	Pests, diseases, alien invasive species	1	1	NK	NK	NK	NK	NK	NK	NK
	Markets, trade and the private sector	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Policies	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Population growth and urbanization	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Other [*pleasespecify*]	-	-	-	-	-	-	-	-	-

15 Description of drivers can be found in Annex 3.
16 Description of ecosystem services can be found in Annex 4.
NK- No knowledge

Table 13. Major drivers and their effect on ecosystem services in production systems related to crops

Production systems	Drivers15	Effect of drivers on ecosystem services 16 (2, 1, 0,-1, -2, NK, NA)								
Code or name		Pollination	Pest and disease regulation	Water purification and waste treatment	Natural hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ Gas regulation
Crops: (C5, C6 C7)	Changes in land and water use and management	1	1	NK	NK	NK	NK	NK	NK	NK
	Pollution and external inputs	1	1	NK	NK	NK	NK	NK	NK	NK
	Over-exploitation and overharvesting	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Climate change	1	1	NK	NK	NK	NK	NK	NK	NK
	Natural disasters	1	1	NK	NK	NK	NK	NK	NK	NK
	Pests, diseases, alien invasive species	1	1	NK	NK	NK	NK	NK	NK	NK
	Markets, trade and the private sector	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Policies	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Population growth and urbanization	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Changing economic, socio-political, and cultural factors	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Advancements and innovations in science and technology	NK	NK	NK	NK	NK	NK	NK	NK	NK
	Other [*pleasespecify*]	-	-	-	-	-	-	-	-	-

15 Description of drivers can be found in Annex 3.
16 Description of ecosystem services can be found in Annex 4.
NK- No knowledge

The increase in the number of threatened species in Oman is mainly attributed to habitat loss because of overgrazing and development. Possible climate change, off-road driving, ecosystem modification and littering are also representing a threat to flora and vegetation of the country (A. Patzelt, in press.). These threats lead to the loss or decline of plant populations. The on-going research in Oman Botanic Garden in documenting plant communities and plant species distribution will help to further identify threats for flora and vegetation.

In case of agriculture and food crops, gradual change of irrigation water and soil to saline in whole of coastal area in Al-Batinah governorates since 1990s due to over irrigation of land causing seawater intrusion to irrigation wells and prolonged droughts faced by the country has also affected agriculture and crops. Most of the indigenous cultivars of crop plants have been lost due to farmers' non-preference to grow these cultivars and preference to adapt plastic houses to grow vegetable cash crops as these proved profitable.

Terrestrial lands of Oman depend mainly on perennial plants with availability of annual plant species, for fodder, only after rain. In Oman, threats to plant species diversity and vegetation cover can also be inferred from land use, rangeland degradation (desertification) and pollution. In 1995, Oman signed the UN agreement on combating of desertification in countries facing severe arid conditions. Mesquite or Ghafbahri (*Prosopis juliflora)* had been introduced in the country three decades ago as a fast growing ornamenting in landscape planting (Al Rawahy *et al*., 2003) and is now been growing in most part of the country and even reaching oil exploration areas. The species is native of southwest US and northwest Mexico (Shiferaw, *et al.,* 2004). First recorded in 1998, *Nicandra physaloides*is native to Peru and has been spreading around mountain settlements of Dhofar (Diwan of Royal Court). Lead Tree (*Leucaena leucocephala)* is now cultivated in home gardens and on sides of the roads. It is seen as a future colonizer. To date, threat of *Prosopis* and *Leucaena* to biodiversity is still undocumented in Oman.

Threats to vegetation have been summarized in Oman Plant Red Data Book as follows:

i. Breakdown of traditional land management practices, including livestock management
ii. Development of human settlements and other non-agricultural land uses with a substantial footprint
iii. Human intrusion and disturbance
iv. Climate change
v. Lack of protected areas for plant conservation
vi. Lack of species management plans
vii. Lack of monitoring of threatened species
viii. Lack of restoration programmes
ix. Introduction of exotic species for agriculture, ornamental horticulture, rangeland management, including overgrazing by livestock and desertification.

In case of fisheries, both natural and human disturbance are affecting marine population in general and fish population in particular. Natural disturbance include physical changes (climatic, tidal and geological events, such as hurricanes, cyclones, storms, sea level rise, volcanic eruptions, and drop in temperature), natural predation (especially in the Indo-Pacific region, by the starfish *Acantha sterplanci*, the gastropod *Drupella rugosa*, sea urchins *Echino metramathaei*, *Heterocentrotus mammillatus, Diadema setosum and Tripneu stesgratilla*), and competition for food and space, which can limit coral growth and the expansion of the coral reef. Human disturbance includes coral and sand mining, and some coastal engineering works, resulting from coastal development; deposits of sediments; and soil erosion and run-off from land clearance, due to bad management and unconcerned management, deleterious fishery-related damage causing coral reef breakage; caused by tangled gill nets and boat anchors., over-fishing or unsustainable harvest of fish and over-exploitation of reef species, intensive recreational activities and resulting litter, rubbish and soil disturbance, oil pollution and discharges from desalination plant and sea farms, industrial, domestic and agricultural pollution, and destruction of other ecosystems such as mangroves and seagrass beds, which help to stabilize coral reefs.

Effects of drivers of change on wild foods:

The effects of drivers affecting availability, knowledge and diversity of wild foods in Oman are presented in Table 14. Many forest trees are known for their wild food such as figs, berries etc. have been gradually found decreased probably because of loss of pollinators due to extreme heat because of climate change and also because of pests and diseases. There has been awareness about the importance of wild food as evidenced by their demand in the market while the interest among the people for their exploitation is not in line with their demand in the market.

Table 14. Drivers affecting availability, knowledge and diversity of wild foods.

Drivers17	**Effect of drivers (2,1,0,-1,-2,NK,NA)**		
	Availability of wild foods	Knowledge of wild foods	Diversity of wild food
Changes in land and water use and management	-1	NK	0
Pollution and external inputs	-1	NK	0
Over-exploitation and overharvesting	-1	NK	0
Climate change	-1	NK	0
Natural disasters	0	NK	0
Pests, diseases, alien invasive species	-1	NK	0
Changing markets	1	NK	0
Policies	0	NK	0
Population growth and urbanization	0	NK	0
Changing economic, socio-political, and cultural factors	NK (No Knowledge)	NK	NK
Advancements and innovations in science and technology	NK	NK	NK
Other [*pleasespecify*]	NK	NK	NK

CHAPTER 3

The State and Trends of Biodiversity for Food and Agriculture

The following are the state and trends of biodiversity for food and agriculture existing in Oman in different sectors (MAF, 2012):

Livestock:

There are many species and breeds in Oman, but numbers of these breeds differ. Some of the breeds within species are classified as breeds at risk. Ministry of Agriculture and Fisheries carries out research to improve the productivity of local sheep and goat breeds through selection. Genetic evaluation and performance recording have been done for some local sheep and goat breeds and their crosses.

It is worth mentioning that there are some goat populations in rural and mountain areas that have not been characterized or identified despite their widespread use in these areas. These populations have distinct phenotypic and productive characteristics which imply that they could be distinct breeds, hence the importance of the need for characterization in the identification of these populations.

Cattle:

Batinah (North of Oman)
The cattle are light brown with medium size, average conception rate - 75%, the average mortality rate -1.8%, average birth weight - 14 kg and weaning weight - 51 kg while the average six-month weight is 63 kg and the average adult body weight is 250 kg. The average daily milk yield 1.8 kg/d. It is found in the northern part of the country and raised under traditional system in backyards and farms. The breed is widely used for meat and milk production.

Dhofari (South of Oman)
They are dark brown with an average conception rate - 69% and mortality rate - 1.5%. Average birth weight is 17 kg and weaning weight - 82 kg. The average six-month weight is 97 kg while the average of adult body weight is 325 kg. The average daily milk yield is 6 kg/d The breed is found in the southern part of the Sultanateand raised under stationary grazing system. The breed is widely used for meat and milk production.

Goats:

Al-Jabal Al-Akhdar (Green Mountain)
Common color is brown. The breed is medium size with average conception rate - 90% and twining rate - 1.29% while average weaning weight is 15.0 kg, six-month weight - 22 kg and average mature body weight is 36 kg. Body is covered with soft hair of moderate length. The head is elongated and of medium size. Noseis curved and ears are of medium size. Legs are moderately long. Both males and females have horns. Tail is short and lifted upward. This breed lives in the valleys and plains of the Interior Governoate and at the foot of the hills at an altitude of 2800 – 3000 m above sea level. The breed is widely used for meat production. Mostof its population is concentrated in the Green Mountain and in the Interior governoate and is mainly raised under medium-input production system.

Al-Batinah
Colors common in this breed are dark brown, light brown and black with white spots in the face, belly, and lower limbs. The breed is of medium size with average conception rate - 92% and twining rate - 1.22 % while average weaning weight - 13.0 kg, six-month weight - 21 kg and mature weight reaches 33 kg. Body is covered with long coarse hair. Legs are short and thick, head is of medium size with somewhat elongated face. It has a straight nose and middle-size ears. Both males and females carry horns. The breed is widely used for meat production and is raised under medium-input production system.

Dhofari
Common color is white with other occasional colors as black, dark brown, light brown and a mixer of colors. It has a small body covered with short soft hair. The average conception rate is 80% and twining rate is 1.13%. Average weaning weight is 12.5 kg while it is 16.0 kg at six-months and about 26 kg at maturity. Legs are short and fine. Head is relatively small with some elongation. Nose is straight and ears are small and erected upward. Both males and females have horns. Tail is long and erected upward. The Dhofari breed is found in the plains and the mountain areas of Dhofar governorate. The breed is raised under medium-input system and is widely used for meat and milk production.

***Sahrawi* (**Desert)
This breed is found in the plains and valleys all over the Sultanate. It is characterized by its solid black colored body with brown stripes around the neck and the belly. Head is small and both sexes have horns. Legs are fine with medium length and ears are also of medium length. The average conception rate is 85 %, twining rate - 1.25%, and mortality rate - 5%. The average birth weight is 2.5 kg and weaning weight - 13 kg while six month weight is 18 kg and yearling weight - 27.0 kg. There are no studies on this breed for characterization.

Jabbali
This breed is widely distributed in the chains of the Al-Hajar mountains especially in Mudaibi, Ibra and Quriyat and found in Al-Dhahira. The breeders made lots of improvement in this breed. It is also called as Rahebi or Sawalem. The color is different from brown to light brown. The head is big and the nose is curved,the ear is small and the tail is short. The average conception rate is 85 %, twining rate - 1.20%, and mortality rate - 5%. The average birth weight is 3.3 kg and weaning weight - 16 kg while the adult weight is 30 kg. There are no studies on this breed for characterization. In addition to the above goat breeds, there are unidentified local breeds utilized by producers, which have good productive traits, i.e. milk production and high twinning rate, but no studies have been carried out on these breeds.

Sheep:
Omani (North of Oman)
Common color is black but a few sheep are white and brown. Average conception rate is 93% and twining rate - 1.30 %. Body size is medium to large with an average weaning weight - 16.0 kg, six-month weight - 25.5. kg and weight at maturity - 34 kg. Body is covered with short coarse wool. Legs are fine and medium in length. Head is small with slightly elongated face. Nose is curved while neck is of medium length without any markings. Ears are of medium length and the udder is medium size with teats varying in length. Males carry horns while females do not. Tail is short and thick and always hangs down. The breed is found in the north of the Sultanate and raised under medium-input production system and widely used for meat production.

Dhofari (South of Oman)
White in color with short legs. The breed is found in Dhofar and used on a small scale to produce milk and meat under medium input production system.

Camels:
There are no accurate surveys on camel breeds but Omani camels are considered as true Arabian camels. They are all one-humped. There are obvious features and differences among different camel populations according to which and to other local knowledge they are characterized into the following groups.

Samha
Common color is dark brown. It is originated in the Interior Governoate and considered a truly race camel.

Musiha
Usually of golden color but yellow in some cases. It is spread all over the Sultanate and originated in Al- Batinah. These camels are raised under high-input production system.

Fariha
Large in size and color ranges from blond to yellow. It is originated in the Al-Sharqiyah Governoates but spread allover the Sultanate. It is used for race and raised under high-input production system.

Khumaisa
Large in size and color is mainly blond. It is originated in the Eastern Governoate and has been used on a large scale in the past for riding but is used now for racing and milk production.

Khiwara
Large in size and dark brown to black in color. It is spread in different parts of the Sultanate, used for riding and racing and raised under high-input production system.

Ramli
Dark brown, large in size with tall legs. Females are characterized by large udder. It is found in the south of the Sultanate, widely used for milk production and raised under medium-input production system.

Khuzami
Light brown, large in size with tall legs. It is found in the southern part of the country. The group is widely used for milk production and raised under medium-input production system.

Jabali
Brown with short legs and smaller than Ramli and Khuzami. It is found in the mountainous areas in the south of the sultanate. Animal are raised under low-input production system for meat and milk production.

Horses:
Horses are usually used for leisure with little use in agriculture. They are not raised on a large scale in the Sultanate. Only few people keep horses and thus there are no field surveys about them.

Poultry:
Local poultry stocks are found in rural areas and raised in households and farms in small numbers. Local poultry is used for home consumption and contributes to some extent to family income. Local poultry is disease resistant, adapted to hot weather conditions and show low mortality. Local chickens have medium length legs with single serrated comb. Plumage color ranges from black, brown to white. The local chicken has a very low production probably because it is raised under traditional system with inadequate inputs. Average daily growth rate is 75-90 g, body weight at 20 weeks of age - 1.3 kg, egg production - 75-80 eggs per year with an average egg weight of 35-45 g. Egg shell is usually white. There exists no information onlocal chickens in the Sultanate but there is some information on commercial chicken production that uses exotic stocks. It can be concluded that priorities in capacity building are needed to understand biodiversity situation of important local breeds, which would focus on training of Omani cadres in the application of genetic improvement techniques using genetic markers, identifying genetic loci affecting quantitative traits and identification of breeds through measuring genetic distances and protein polymorphism. Also, among the priorities is the characterization of the non-characterized populations in the rural areas. The group is spread all over the Sultanate and usually raised under high-input production system.

Forests:
Recent count of the plant species composition in Oman yielded a total of 1,200 documented flora species (A. Patzelt, *in press*). The conservation status of 261 plant species is assessed in the National Red List; 189 of those are range-restricted (A. Patzelt, in press.). 6.5% (78 species) of all species are endemic to Oman and cannot be found elsewhere in the world, and 9.3% are near-endemic or regional endemic (A. Patzelt, in press.). At total of 9.1 % of the flora is considered threatened (A. Patzelt, in press.). Endemism is at its highest in the southern region where 46% of the species are threatened (Ghazanfar, 1998). Of a total of endemic and regionally endemic species, 63 are present in Dhofar, 12 in central Oman and 25 in the northern mountains. Regionally endemic species existing in Oman are distributed in the western region of Dhofar and eastern Yemen. However, the cover and the individual numbers of flora are decreasing mainly in the north of Oman.

Of the marine forests, only *Avicennia marina* thrives distributed in the northern and southern coasts on the edges of small sea inlets. *Rhizophora mucronata* has been introduced in small areas in the Dhofar coasts. Also in the brackish water lagoons (khawrs) in Dhofar is a distinctive *Ceratophyllum demersum, Potamogeton pectinatus,Najas marina* and *Chara spp.* In partnership with JICA, mangrove afforestation had been engaged with the Sultanate in April 2000. A Japanese mangrove expert was sentto then MRMEWR (now MOECA) to spearhead an *Avicennia marina* afforestation programme. The marine mangroves Sediments from 6000 years ago revealed the presence of pollen from *Avicennia marina* and *Rhizophora mucronata* mangroves. At present, the nearest *Rhizophora* mangrove is found on the southwestern end of the Arabian Peninsula in Yemen and in the Sirik estuary of Iran. *Brugiera gymnorrhiza* is recorded as extinct in Yemen though still present in Somalia.

Aquaculture and Fisheries:

The lagoons of Mangrove and the *khawrs* of Oman are still subject to damage from rapid development to include the following issues: a) port and fishing boat, harbor construction that requires damaging landfill and dredging causing coastal erosion and sedimentation; b) road construction; c) tourism and recreation; and d) solid waste and water pollution.

In this habitat, the following main needed actions deserve attention: a) sustainable utilization and biodiversity conservation; b) planting and new locations; c) seed provenance; d) mangrove nurseries

(Figure 9); e) monitoring; f) education and awareness; g) existing facilities; h) information sharing and communication; i) coordination; and j) Omanization.

In the wake of tropical cyclone “Gonu”, environmentalists in Oman have intensified efforts to create a natural wall of mangrove forest to thwart any tidal threat along the country's coastline.

Figure 10: Areas of major coral growth in the Sultanate of Oman (marked with circles).

Mangroves protect the coast from erosion, surge storms, especially during hurricanes, and tsunamis, especially that the mangrove forests' massive root system is efficient at dissipating wave energy.

Coral communities of the Sultanate of Oman present unique characteristics that are to be preserved. These coral reefs are distinct from those in others areas of the Arabian area, which are already distinct from the rest of the Indian Ocean. In the Sultanate of Oman, major coral growth is restricted to four areas: the Musandam Peninsula; the rocky shores, bays and islands in and adjacent the Muscat area (Gulf of Oman); the straits, shallows and shores west of Masirah Island (Arabian Sea); and some isolated sheltered locations in Dhofar and the Al Hallaniyat Islands. Other parts of the coast of the Sultanate of Oman, either lack corals or have limited growth of small, scattered colonies, due mainly to the absence of suitable substrate (e.g. along the sandy Batinah coast), or to seasonal upwelling of cold water on the Arabian Sea coast. Most of the sub-littoral zone of Oman is soft substrate, but the variety of the coastal morphology and hydrological regime also leads to a variety of biotic zones or biotopes. The Coral reefs throughout Oman are threatened by large scale, irreversible damage and the continued devaluation or loss of coral reef resources, including those currently of value to fisheries, tourism and recreation, coastal protection, scientific study, marine biodiversity and marine ecology. Natural impacts on Oman’s coral reefs indicate unusual and stressful conditions that corals in the Sultanate must tolerate. Principal impacts are: Fishery-related damage causing coral reef breakage, caused by tangled gill nets and boat anchors; coastal destruction; litter; recreational activities; oil pollution; discharges from desalination plant; enriched water discharges from sea farms.

The Omani aquatic ecosystems are unique in the sense that their locations are in an arid region and that their biodiversity composition has evolved into species that had been resilient of the almost harsh and dry environment. Therefore, any significant perturbation to their natural environment will result in the biodiversity's eventual extinction. Aquatic communities include the spring-streams and *Wedian* (plural of *Wadi*). Streams originating from springs (*ayns*) could be natural or man-made *aflaj* (plural of *falaj-water channel*). Springs usually originate in the mountains or in the foothills of mountains. The Ministry of Water Resources has reported 69 important springs in the Sultanate of which 45 are cold and 33 are thermal. Of the total, 64 also yield potable water. Local rainfall patterns in the watershed affect the number of active streams at any given time. Floods affect the structuring and restructuring of habitats in the Wedian. On the biodiversity point of view, only Muaydin drainage at Birkat al Mawz had been studied yielding 33 invertebrates and three vertebrate taxa were recorded in a1.5-km strength of the wadi (Victor and Al Mahrougqi, 1996 as cited by Victor, 2000).

There are no large natural freshwater lakes in Oman. However, in Wadi Darbat in the Dhofar region, the wadi pools merge to form lake-like conditions immediately after the khareef or monsoon. The pools shrink in size during the dry winter period. There are also reservoirs, ponds or pools and khwars in other parts of the country. Khwars in northern Oman are mostly brackish and sometimes hyper saline, while many in the Dhofar region remain freshwater for most part of their hydrological cycles. Important retention reservoirs are found in Jabal Akhdar area. Temporary ponds are those that dry up during most of the months of the year but refill briefly during rains while astatic pools are temporary with unpredictable pattern of recurrence. Thriving in such ponds are the ciliates, rotifers, copepods, *Cladocera* and *Ostracoda.* Some macro crustaceans like shrimps (*Anostraca*), tadpole shrimps (*Nostraca*) and clam shrimps (*Conchostraca*) occur in these habitats (Victor, 2000). Khwars are best studied in the Sultanate. The biota included the fringing terrestrial and aquatic macrophytes (Ghazanfar, 1998), micro invertebrates, crustaceans macrofauna, mosquitoes, fish and birds by various scientists. Knowledge of aquatic macrophytes in Oman is very poor. In the retention reservoirs of the Western Hajar Mountains, *Potamogeton nodosus* dominated the macrophytes. Some species of micro/macro crustaceans, insects, freshwater mollusks, leeches, nematodes, other invertebrates, had been recorded but many species has to be identified or species to be verified. Oman has seven species of freshwater fish. Several exotic fish species have started establishing populations in the wild which is a threat to the environment. Tadpoles of *Bufo arabicus* and *Bufo dhufarensis* are common in the freshwaters of northern and southern Oman, respectively (Victor, 2000). Overgrazing of vegetation in watersheds contributes to erosion and consequent severe siltation of *khawr* areas and the productive near shore marine environment. Feral animals like dogs, cats, goats, donkeys, introduced rats are potential threats to wildlife leading to potential extirpation of sensitive species. Other issues raised reveal the following: a) Beaches and camping sites and scenic areas are fouled by litter, b) Drying of sardines and discard of fish offal, old nets, oil drums, rusted freezers and other litter on fish landing beaches diminishes their value for recreation, c) People lacking support of fisheries resource management due to ignorance or inadequate knowledge and information, d) Gross wastage of fishes together with the capture of undersize and berried crayfish is depleting fishery resources, e) Polluting beaches, and potentially threatening some species, notably crayfish, sharks and groupers with local extermination, f) Coastal archeological sites are being lost to coastal development, damaged by vehicle traffic and road works, looted by amateurs or degraded by litter before they are studied, g) Human predation of breeding seabirds and their eggs has resulted in local extermination of breeding colonies, h) Mangroves , reeds and rushes are endangered by development pressure, overgrazing, infilling, pollution and dumping of garbage, i) Intermittent illegal discharges of oil at sea off the coast contaminate the beaches with oil and tar balls, destroy their recreational value and threaten the breeding seabird colonies, j) Escalating sand mining activities or the demand for sand by new

development schemes could lead to disappearance of smaller beaches, k) Careless fishing practices are damaging corals thereby reducing aesthetic value of reefs for recreation, and their productive value for fisheries, through entanglement of nets, ropes and anchors, l) Enriched waste water from inland containment lagoons enters the *khawrs* and solid wastes are dumped in the *khawrs*, mangroves and *wadis*, on the beach and into the sea, m) Coral reefs in much of Mussandam are being devastated by the Crown-of-thorns Starfish (*Acanthaster planci*) and temperature-induced bleaching of the corals, n) Breeding population of turtles are threatened by collision with the high speed boats of Iranian traders and heavy oil and flotsam pollution of their nesting beaches, o) Gunnery target practice by Royal Navy of Oman causes disturbance to seabirds, p) Tourism village, fisheries and other development projects may create the need for new or upgraded roads and improved access to the seashore could stimulate beach erosion, damage coastal environments and reduce their value for recreation, wildlife and fisheries, or lead to further loss of beaches. Little is known about the population status of cetaceans in the waters of Oman. The Environment Society of Oman (ESO) had collected sufficient data by photo identification techniques only for the Humpback Whale. There is also historic whaling data for this species which enables a limited understanding of historic abundance and so a rudimentary trend assessment has been possible. The results of this work indicate very conclusively that Humpback Whales occur in very low numbers in Oman (Baldwin, 2009), with a best estimate of just 82 individuals remaining in the population (95% CI 60-111, Chapman/Petersen Index). Oman's population of humpback whales is therefore genetically unique, and in severe danger of extinction. IUCN has declared the population Endangered (see attachment) based on its low numbers and limited regional range and it is widely acknowledged that this is one of the rarest baleen whale populations in the world.

ESO's involvement in turtle research in Oman is currently focused on Loggerhead Turtles nesting on Masirah Island. This has included systematic data collection according to rigorous scientific protocols undertaken over the past two years that have allowed for preliminary estimates of abundance. When pooled with previous data, albeit collected in a non-systematic and less scientific manner, some analysis of trends has been possible. These data suggest that the historic nesting population of Loggerheads on Masirah Island was in the region of 30-40,000 females in the late 1970's, but has declined since this time to a level of perhaps 20-25,000 by the early 1990's and to an estimated minimum of 12,000 by 2008 (Baldwin, 2009). This decline is similar to that experienced by the only other comparably large population of this species in the world, namely that of the Eastern United States (Florida), as well as most other populations globally. Oman would therefore appear to be no different to other nations of the world in experiencing severe decline in its nesting Loggerhead population. However, Oman has a greater responsibility than most countries to implement conservation measures to prevent further decline, or indeed enhance recovery, owing to the fact that its population remains one of the two largest in the world and probably still constitutes up to 40% of all nesting females. ESO has also been involved with assessment of Hawksbill Turtles nesting on the Daymaniyat Islands. No population estimate has been attempted, but ecologiecological evidence suggests that the nesting population is at, or very near to, carrying capacity.

Macro-algae Trends

There have been few studies on the macroalgae of Oman, e.g. the survey mainly for commercial potential of seaweeds by Mardela Int. (1975) listed around 30 taxa identified mostly to generic level. A list of seaweed taxa is given in Barratt *et al.*, (1984). The study showed the brown algae as abundant around Masirah (Figure 12). Further studies are needed to show the trends of the Macroalgae. More recently, a study on the Delesseriaceae (Rhodophyta) of the Arabian Sea was undertaken. Representatives of this family are relatively well documented for adjacent areas in the Indian Ocean

and these taxa are consequently a good tool for biogeographical analyses. The morphology, anatomy and reproductive characteristics of ten species are being studied; including taxa with disjunct distribution patterns (e.g. *Zellera* sp.) and first records since their original description (e.g. *Chauviniella jadinii*). Other algal groups that require a thorough examination are the Chlorophyta, the Nemaliales and the Rhodymeniales. The record of a true Kelp species *Ecklonia eadiata* that is found at depth between 6 and 12 meters in a tropical region is of great biodiversity interest as it is otherwise reported only from South Africa, Australia and New Zealand. The presence of this exceptional record of a temperate species has not recently been confirmed since despite attempts (most recently in 2009) to find it. It is possible that the species is confined to a much localized site east of Sadh, Dhofar; further efforts should be made to confirm its presence. Apparently, the sea currents play a big role in the redistribution of algal species.

Sea-grasses Trends

Distribution, abundance, and biomass data for seagrass communities at several locations on the coast of Oman were studied. The main study site was on the western side of Masirah Island on the Arabian Sea coast of Oman. This area is an important feeding ground for the green turtle, *Chelonia mydas* L., and it is affected by upwelling of low temperature waters during the summer monsoon. The depth distributions of *Halodule uninervis* and *Halophila ovalis* (Figure 13), the two most abundant seagrasses at this site, overlapped but were inversely related. *Halodule* dominated the intertidal zone and *Halophila* was more predominant in the deep subtidal, although total biomass of the two sea grasses were similar in this depth zone. At all depths, biomass of *Halophila* was about equally distributed between leaves and roots and rhizomes. Leaf biomass of *Halodule* was only 7–20% of the total biomass and the highest below-ground biomass occurred in the intertidal zone. Biomass of these species here and at other sites and of *Thalassodendron ciliatum* (Forssk.) den Hartog at this site was generally lower than comparative data in the Gulf and the Red Sea. Small patches of *Syringodium isoetifolium* (Aschers.) Dandy was also observed in Umm Ar Rasas Bight making a total of four species recorded to occur in Oman. The reduced growth of seagrasses at Masirah Island seems to be due to stresses associated with the summer monsoon and grazing pressure. Survival of these populations is discussed in terms of seasonal growth and flowering. The Gonu Cyclone which caused extensive damage in 2007 along the Sea of Oman was the strongest tropical cyclone on record to hit the Arabian Peninsula. The dense beds of the smaller seagrasses *Halodule uninervis* and *Halophila ovalis* in the shallow intertidal at Ra's Sawadi apparently were destroyed by this cyclone.

Crops:

Oman has a wide diversity of crop plants for diet and food or feed purpose in addition to other human use. A number of field crops, vegetables, fruit trees, forest trees, rangeland pasture species, aromatic and medicinal plant species are indigenous and known to be grown in the Sultanate since immemorial time. Table 2 lists main species for food and agriculture of Oman. Among these the most important ones are dates, banana, acid lime, mango, wheat, barley, chickpea, onion, garlic, sweet potato, cucumber, watermelon etc. With the exception of maize, oats, and sunflower, all the other species are considered indigenous.

Oman has not only several local adapted cultivars and land races or ecotypes of crop species such as Coola, Missani, Humaira, Walidi etc in wheat but also wild relatives of some crop plants that form the source of material for crop breeding to transfer specific characters.

Table 2. Main species for food and agriculture of Oman (in order of importance for each category)

Category	Crop Species
Field crops	*Triticum aestivum* and *T. durum* (wheat), *Hordeum vulgare* (barley), *Avena sativa* (oats); *Sorghum bicolor* (sorghum), *Zea mays* (maize), *Cicer arietinum* (chickpeas), *Vigna unguiculata* (cowpea), *Sesamum indicum* (sesamum), *Carthamus tinctorius* (safflower), *Helianthus annuus* (sunflower), *Gossypium* sp. (cotton), *Saccharum officinarum* (sugarcane), *Medicago sativa* (alfalfa), *Pennisetum purpureum* (elephant grass), *Nicotiana tabacum* (tobacco)
Vegetable crops	*Allium sativum* (garlic), *Allium cepa* (onion), *Citrullus lanatus* (watermelon), *Cucumis melo* (muskmelon), *Daucus carota* (carrot), *Ipomoea batatas* (sweet potato), *Cucumis sativus* (cucumber), *Raphanus sativus* (radish), *Abelmoschus* spp. (okra), *Lycopersicon esculentum* (tomato), *Lactuca sativa* (lettuce), *Brassica oleracea var. capitata* (cabbage), *Brassica oleracea var. Botrytis (*Cauliflower), *Cucurbita maxima* (squash) and *Solanum tuberosum* (potato)
Fruit tree crops	*Phoenix dactylifera* (date palm), *Mangifera indica* (mango), *Citrus aurantifolia* (acid lime), *C. limetta* (sweet lime), *Punica granatum* (pomegranate), *Vitis vinifera* (grape), *Carica papaya* (papaya), *Musa paradisiaca* (banana), *Psidium guayava* (guava), *Cocos nucifera* (coconut)
Wild forest trees, shrubs and pasture species	*Prosopis cineraria, Acacia tortilis, A. ehrenbergaina, A. senegal, Anogeissus dhofarica, Maerua crassifolia, Ziziphus, Olea europaea, Blepharispermum hirtum, Calligonum comosom, Euclea schimperi, Pteropyrum scoparium, Maytenus dhofarensis, Cenchrus ciliaris, C. setigerus, Apluda mutica, Themeda quadrivalvis, Dactyloctenium aegypticum, Panicum turgidum, Pennisetum divisum.*
Aromatic and medicinal plant species	*Boswellia sacra* (frankincense), *Lowsonia inermis* (henna), *Datura fastuosa* (datura)

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

Oman has many wild plants in its ecosystems that were earlier harvested for food directly or indirectly. These include: *Amaranthus graecizans, Arisaema flavum, Remusatia vivipara, Glossonema varians, Pentatropis nivalis, Caralluma flava, Rhytidocaulon fulleri, Ceropegia bulbosa, Cibirhiza dhofarensis, Raphionacme arabica,Adansonia digitata, Cordia perrottettii, Commiphora habessinica, Boscia arabica, Hydnora africana, Gladiolus ukambanensis, Delonix elata, Tamarindus indica, Ormocarpum dhofarense, Abelmoschus esculentus, Dorstenia foetida, Ficus sycomorus, Ficus vasta, Moringa peregrina, Commicarpus boissieri, Habenaria myodes, Portulaca oleracea, Ziziphus leucodermis, Z. spina-christi, Z. muritania, Citrus aurantifolia, Grewia villosa, Premna resinosa, Cyphostemma ternatum, Pteropyrum scorparium, Thymus vulgaris Trigonella fenum-graecum, Prosopis cineraria, Monotheca buxifolia, Rumex vesicarius,* and *Ceratonia oreothauma* sub sp. *oreothauma.*

The state of diversity of indigenous and exotic varieties

Farmers have selected and conserved landraces and local cultivars in a dynamic way since they started cultivation of crops (Table 3). 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.

Table 3. Indigenous cultivars and/ or landraces of different crop species in Oman

Crop	Local cultivars/land races
Acid Lime (*Citrus aurantifolia*)	Local (Lomy)
Alfalfa (*Medicago sativa*)	Bathini, Interior, Sharqiya, Rustaq, Quriati
Banana (*Musa* sp.)	Fard, Barshi, Nagal, Somali, Malendi, Red
Barley (*Hordeum vulgare*)	Bathini, Doraqui
Ber (*Zizipus mauritiana*)	Seeded, Seedless (Maqatmani)
Carrot (*Daucus carota*)	Local
Chickpea (*Cicer arietinum*)	Local
Coconut (*Cocos nucifera*)	Local , Al-Malki
Cotton (*Gossipium arboreum*)	Brown
Cowpea (*Vigna unguiculata*)	Brown, Black, Mottled
Cucumber (*Cucumis sativus*)	Local, Dhofari
Datepalm (*Phoenix dactylifera*)	186 Landraces
Garlic (*Allium sativum*)	Bahla, Rustaq,Tanuf, Jimah
Grape (*Vitis vinifera*)	Black ,WhiteRed
Guava (*Psidium guajava*)	Red, White
Maize (*Zea mays*)	White, Red , Yellow
Mango (*Mangifera indica*)	Al-ward, Al-khokh, Al-halqoom, Quriate-15, Rumais-89, Muscati .
Onion (*Allium cepa*)	Local
Papaya (*Carica papaya*)	Local seedy strains
Pearl millet (*Pennisetum glaucum*)	Tall local
Pomegranate (*Punica granatum*)	Malasi, Jabal akhdhar
Radish (*Raphanus sativus*)	Local
Safflower (*Carthamus tinctorius*)	Local
Sesame (*Sesamum indicum*)	Local
Sorghum (*Sorghum bicolor*)	Red, White
Sugarcane (*Saccharum officinarum*)	Bahlawi, Nizwawi, Dhofari
Sweet Lime (*Citrus limetta*)	Burgab, Daire
Sweet melon (*Cucumis melo*)	Local
Sweet Potato (*Ipomoea batatas*)	Red, White
Tobacco (*Nicotiana tabacum*)	Suwaida, Musdaria, Fannashia, Omlaein, Hitathi
Wheat (*Triticum aestivum*)	Coolah, Saraya, Hamira,Waledi, Missani

In the past 20 years, a number of improved cultivars have been introduced in Oman. Most of these cultivars are from breeding programs carried out by CGIAR centers, as well as multinational companies. Introductions have undergone an evaluation and selection process for their performance and adaptability to local conditions.

Overall the introduction of exotic improved cultivars had a great impact on the displacement of local varieties of cereals and forages (Table 4), and vegetable crops, due to improved performance and market acceptability of the new cultivars. Local varieties of these crop groups are still grown in some areas of Oman, namely, Ad'Dakhliah, As'Sharqiah and Ad'Dhahirah, where subsistence-farming systems predominate.

With regard to fruit trees, such as date palm, lime, pomegranate and coconut, new cultivar introductions have been very limited as the local varieties are more adapted to local conditions and still offer comparative advantages over international cultivars in terms of yield and, in the case of date palm, quality. On the contrary, in mango and banana the indigenous cultivars have been found to be less productive.

Table 4. List of recommended exotic improved varieties in field and forage crops

Crops	Varieties
Wheat	Mexipak, Sannine, WQS151, WQS160, WQS302, WQS305, WQS308, Jimah1, Jimah2, Jimah 101, Jimah 102, Jimah 103, Jimah 107, Jimah 110, Jimah 125, Jimah 132
Barley	Beecher, Jimah5, Jimah6, Jimah 51, Jimah 53, Jimah 54, Jimah 58, Jimah 98, Jimah 136
Cowpea	Jimah 2, Jimah3, Jimah 4
Chickpea	ILC237, Jimah7, Jimah8, Jimah 1, Jimah 2, Jimah 17, Jimah 18
Dry peas	ARC-2 (Rumais2), ARC-3 (Rumais3), ARC-4 (Rumais4), ARC-5 (Rumais5), (ARC-6 (Rumais6), ARC-7 (Rumais7)
Mungbean	PS-16, Sona, PDM 84-13
Sesame	Giza 23
Safflower	A-300, A-1
Sunflower	Turkey-79, Miak
Maize	Giza2, Katamani503, Hybrid 622, Irat8, Sohar1, Sohar2, Rumais Composite 1, Rumais 2, Rumais Composite 3
Sorghum	Sugar drip, Honey drop, Fs x Dekalb 17
Fodder Oats	Marloo, ARC-1 (Rumais1)
Rhodesgrass	Callide, Katamboa, Samford, Elamba, Boma, Pioneer
Alfalfa	ADLL 6725, CUF 101, Cundor, DK 187, Maxidor, Sequel
Fodder beet	Peramono, Petra, Anissa

Crop wild relatives:

Existing flora of Oman, in particular in the Dhofar governorate, include crop wild relatives of several species used for food and agriculture.These include species belonging to genera- *Abelmoschus, Amaranthus, Cenchrus, Chloris, Citrullus, Citrus, Cucumis, Desmodium, Dichanthium, Ficus, Gossypium, Indigofera, Ipomoea, Lactuca, Lavandula, Ocimum, Panicum, Paspalum, Pennisetum, Pistacia, Ricinus, Saccharum, Setaria, Solanum, Sorghum, Vigna* and *Ziziphus*.

Factors affecting state of diversity

Although systematic *in situ* and on-farm surveys on the state of inter and intra-specific plant diversity have not been sufficient, there is evidence of an increasing pressure from several abiotic, biotic and social factors on this diversity. These factors include: i. Soil and water salinity; ii. Overgrazing and deforestation of rangelands, iii. Replacement of local cultivars by high yielding modern cultivars; iv. Climate changes causing extreme high temperatures and drought; v. Pests and diseases, especially viruses and virus-like diseases; vi. Urbanization of the exterior range/ mountainous lands; and, vii. Scarcity of irrigation water affecting farming diversity.

The most detrimental impact of many of the above factors can be expected firstly on marginal and subsistence farming systems, By definition, these are the most vulnerable ones, and as previously discussed are those that use and conserve the widest plant diversity in the country.This is inevitably posing a serious threat to the very survival of Omani indigenous crop species, cultivars, landraces, ecotypes, and wild relatives and a challenge to the institutions of Oman for reversing this trend through activities of collection and conservations.

The State of In Situ Management

In situ conservation and management of PGRFA in the country are carried out by both MAF and Ministry of Environment and Climatic Affairs (MECA). MAF is concentrating on the conservation and management of indigenous landraces of field crops, vegetables, and pasture plant species, whereas MECA has reserved areas in different parts of the country with aim of conserving the ecosystems.

Plant genetic resources surveys

With regards to domesticated plant species, activities of surveying have been limited to some missions for collecting ecotypes and/or varieties of wheat, barley, and some vegetables (Guarino, 1990) and rangeland species undertaken by MAF in collaboration with ICARDA-APRP in all governorates of Oman (Osman et al. 2002). These activities mainly aimed at describing the state and distribution of all Omani indigenous cultivars/species for food and agriculture without involving crop wild relatives. Later, several collection missions were undertaken by the local staff. However, it is essential to improve the quality of activities of PGRFA inventorying, surveying and collection, involving participation of experts from the international organizations.

Conservation of wild PGR in protected areas

In Oman, there exist protected areas under the MAF in the vast rangelands of Dhofar (Southern Oman). These are monitored by the staff of the Rangeland and Forestry Department to conserve and protect rangeland, pasture and wild crop relative species from grazing animals. Currently, MAF has maintained as many as 20 fenced areas in the ranges that cover about 171 ha, which accommodate approximately 177 thousand pasture trees of different species. These areas include several rangeland grass and herb species as well as many wild crop relatives and wild plants for food (MAF, 2005a). Ministry of Environment and Climatic Affairs is simultaneously maintaining reserves of different dimensions throughout Oman from as low as 1 sq. km to as high as 24,785.4 sq. km. that supposedly host wild/ weedy crop relatives and rangeland species. It is expected that with the recent establishment of Steering and Executive Committees of PGR, the activities concerning monitoring and surveying of all the plant species present in these reserves, would be strengthened.

Ecosystem management of PGR outside protected areas

The Government of Oman has established several developmental projects aiming ecosystem management for sustaining biodiversity. For instance, of late, ever-increasing livestock number (camels and cattle) has exerted great pressure on grazing pasture flora of mountains and rangelands of Dhofar governorate and affected adversely on the integration of the ecosystem. In this respect, the project on ecosystem management for conservation of rangelands in Dhofar has been working on containing huge livestock population. There were 245 thousand cattle and 79 thousand camels during 2004.These populations were lessened significantly (174 thousand cattle and 53 thousand camels) during 2005 (MAF, 2005a), thus reducing the burden on the rangelands. However, such projects need to be continued for sustainable conservation and management of rangeland ecosystems of Oman.

On-farm management and improvement of PGRFA

There exist numerous activities towards conservation of local land races of vegetable crops such as onion, garlic, cucumber, sweet potato, and muskmelon, and grain crops such as wheat, and barley, through on-farm management since early 1990s. In case of vegetables, MAF takes responsibilities of collecting the most important indigenous ecotypes of vegetables and growing them to multiply seed in isolation in selected sites at research stations. The seed is distributed among interested farmers for commercial cultivation. In case of wheat and barley, selected landraces are cultivated in sites of selected farmer fields for seed production. The seed so produced is purchased by MAF and distributed among farmers for cultivation to promote sustainable agriculture. However, there is a need for extending such activities towards improving indigenous landraces of other crops of PGRFA.

The State of Ex Situ Management:

The state of collections and conservation

Collections

A rational and targeted collecting strategy of indigenous plant genetic resources is at the base of a sound *ex situ* conservation system. In the past 30 years, several missions have been conducted for collecting germplasm of crops grown in Oman. First collections were undertaken jointly with the International Bureau of Plant Genetic Resources in 1980, 1987, and 1988 (Al-Zidjali, 1996). More than six hundreds of these collected accessions of about 270 species are conserved by international centers such as ICARDA and national institutes such as USDA.

Since 1996, several missions have been carried out by the Ministry of Agriculture and Fisheries in collaboration with regional and international organizations. Two missions were conducted jointly with ICARDA: the first one in 1998 where 68 seed accessions of both forage and pasture species were collected from the northern parts of Oman (Ferguson, 1999); and the second one in 2002, where 23 seed accessions of both forage and pasture species were collected from the mountains of southern (Dhofar) governorate (Osman *et al*, 2002). Additional collections have been made since 2000 in collaboration with the International Center of Biosaline Agriculture addressing barley (Jaradat *et al.*, 2004a, 2004b and 2005).

Further collection missions were also conducted by graduate students and employees of institutes that deal with plant genetic resources such as the Ministry of Agriculture and Fisheries, the Sultan Qaboos University and the Royal Gardens. During these missions alfalfa (Al-Hinai, 2004), wheat (Al-Khanjari, 2005), and cucumber (Al-Rawahi, 2008) landraces were collected and placed in their local conservation facilities.

During 2008- 2010, joint MAF-SQU collecting mission of indigenous legumes germplasm was undertaken by the staff of Ministry of Agriculture & Fisheries and the Sultan Qaboos University for their conservation to avoid their extinction due to new emerging abiotic (temperature, salinity, drought) and biotic (insect pests diseases) stresses being faced by the climate change and ensure food security of the country. The mission had led to the collection of total 303 seed samples of land races/ accessions of nine legume crops from seven governorates. 187 seed samples of land races/accessions of seven food legume crops were collected from 110 sites. Wide diversity, in terms of the most accessions collected, was found in cowpea (*Vigna unguiculatasubsp. unguiculata*) (64) followed by faba bean or broad bean (*Vicia faba*) (41), field peas (*Pisum sativum*) (27), mung bean (*Vigna aureus*) (25), chickpea (*Cicer arietinum*) (13), lentil (*Lens culinaris*) (11) and pigeon pea (*Cajanus cajan*) (6).

South Batinah had the most legume accessions collected (70), mainly from Rustaq, followed by Interior (66), Sharqiya (63) Dhahira & Buraimi (46), Dhofar governate (23) and North Batinah (15). In alfalfa (Medicago sativa), 67 seed samples/accessions were collected from 62 sites, with the most (25) from Sharqiya, 20 from Interior, 8 each from North Batinah and Dhahira & Buraimi, 6 from South Batinah and none from Dhofar. In fenugreek, 49 seed samples/accessions were collected from 43 sites, with the most from Batinah South (14) represented mostly by Rustaq, followed by Interior (13), Sharqiya (12) and Dhahira & Buraimi (10). These accessions were placed under local conservation facilities

It is worthwhile to mention that the reported collections serve in either specific national research purposes or international collaborative programs. To better meet the needs of a rational PGRFA conservation and utilization strategy, collection missions should serve to fill the gap between the inter- and intra-specific diversity conserved *ex situ* and the diversity existing *in situ*. Therefore, collection missions should cover the whole spectrum of plant genetic resources such as major crops, minor crops, underutilized species, and forages, wild plants for food and agriculture, and wild crop relatives. The urgency to carry out planned and targeted collecting missions depends on the rate of loss of these resources both *in situ* and on-farm. In this regard, the government awareness should be timely raisedin order to allocate sufficient funds for such activities either through the Agriculture and Fisheries Development Fund (AFDF) or The Research Council (TRC). Cooperation with international organizations, such as Bioversity International and ICARDA, should be sought for these activities.

Conservation

The Seed Technology Unit has been established during 2004 in collaboration with ICARDA that contains almost all the requirements of seed activities. This Unit has been upgraded to National Seed Gene Bank in 2007.As per locally conserved germplasm,an *ex situ* field genebank of 186 date palm accessions was established in 1988.Later,several other field genebanks were established.These include field genebanks of 100 mango accessions in Sohar, 40 banana accessions in Salalah and 23 *Citrus sps* (both indigenous and exotic) in Jimah and Sohar. In addition, field genebanks that can accommodate 244 pasture plants and 101 medicinal plant species were established at Rumais between 2004 and 2005 (Nadaf *et al*., 2004 f and MAF, 2005c). Presently, there are collectively about 100 species of pasture and medicinal plants.

Filling in the gaps of existing collections is just one of the priorities for *ex situ* conservation. Other priorities in Oman include the development and adoption of technologies for low-input conservation and for cleaning collections from pests and diseases. The national program should look for conservation technologies that are affordable especially for short term or active collections.

Documentation and characterization

Germplasm documentation is essential for an efficient utilization of conserved plant genetic resources for food and agriculture. There are many unpublished studies with respect to characterization of indigenous plant genetic resources for food and agriculture like dates, mango, banana, sweet-lime, acid-lime, cucumber, barley, and alfalfa and pasture plant species since 2001.

Ministry of Agriculture and Fisheries has recently initiated activities concerning documentation of PGRFA. The Ministry established a collaboration activity with Bioversity International (formerly, IPGRI) of the CWANA region in developing an information system for managing collections of the plant genetic resources. This system is currently executed and managed by the staff of the Directorate General of Agriculture and Livestock Research (DGALR).

Role of botanical gardens / 'Ex Situ (Field) Genebanks

1. Two botanical gardens exist in Oman- one in the Sultan Qaboos University and another in the Natural History Museum of the Ministry of Heritage and Culture. These include not only PGRFA but also other plant species. These botanical gardens are aimed mainly for education purposes.
2. The Ministry of Agriculture & Fisheries established several field genebanks of different fruit tree species since 1988 in different locations of the Sultanate of Oman, as follows:

Sl. No.	Fruit tree	Location
1	Date palm	Wadi Quriyat, Al-Dakhliyah
		Al-Kamil & Al-Wafi, Al-Sharqiyah
		Al-Rafah Farm, Tanuf, Al-Dakhliyah
		Al-Rafed Farm, Nizwa, Al-Dakhliyah
		Al-Gaaf Al-Sheeq Farm
		Agriculture Research Station, Sohar
		Diba Fruit Nursery Farm
2	Banana	Agriculture Research Station, Salalah, Dhofar
		Agriculture Research Station, Sohar, North Al-Batinah
3	Citrus spp.	Jimah Research Station, Al-Dakhliyah
		Tanuf farm, Al-Dakhliyah
		Agriculture Research Station, Salalah, Dhofar
		Qairoon Hairiti Farm, Dhofar
		Barka Nursery Farm, South Batinah
		Agriculture Research Station, Sohar
		Al-Sharji, Al-Sharqiyah
4	Mango	Agriculture Research Station, Sohar
		Agriculture Research Station, Salalah, Dhofar
		Barka Nursery Farm, South Batinah
5	Guava	Agriculture Research Station, Sohar
6	Coconut	Agriculture Research Station, Salalah, Dhofar
7	Olive	Seiq farm, Jabal Al-Akhdar
8	Deciduous tree	Jabal Al-Akhdar Farm
		Agriculture Development Farm
9	Pasture plant species	Agriculture Research Station, Rumais
10	Medicinal plant species	Agriculture Research Station, Rumais

3. Oman Botanic Garden' has been established near Al-Khod village of Seeb Wilayat, Muscat by the office of the Advisor for Conservation of the Environment, Diwan of Royal Court, where almost all the indigenous grass, herb, shrub and tree species are being preserved in *Ex Situ*.

Impacts of changes in biodiversity for ecosystem services and the socio-economic and cultural implications of these impacts

There is a strong relation between people and their environment as well as their natural resources. This relation is essential and should satisfy both humans and natural resources. In other words, humans and biodiversity should be in balance to ensure the sustainability. As such, people will have to promote development that will not alter the balance and condition of the natural ecosystems. In Oman, the following impacts of the changes in biodiversity are:

- Larger numbers of cattle, sheep, goats and camels have exceeded the carrying capacities of the grazing areas and caused the deterioration of vegetation composition and subsequently decreased the biomass productivity.
- Desertification had encroached on Dhofar Mountains due to heavy over stocking and little application of rangeland management practices.
- This has led to significant deterioration in rangeland, a matter that pushed the owners of herds to purchase alfalfa and hay from farms.
- Hydro-geological instability still represents an overall natural threat. In addition risks for human health and natural environment by pollution in several areas of Oman should be put in a safer state and decontaminated. Otherwise, there will be a need to purchase water from abroad and to pay a huge bill for the health of people.
- Climate variation that caused the Super-Cyclone *Gonu*, which entered the Sea of Oman in June 2007, has led to Oman's worst natural disaster and the largest Cyclone on record to strike the Arabian Peninsula. Highest winds were over 260 km/h in the Arabian Sea and the storm severely damaged coastal areas including 1,000s of sq m of reef damaged near Muscat. The "*Gonu"* emphasizes how well managed wetlands, river basins watersheds are important to mitigate the climate change events.
- Over use of water for agriculture has resulted in salt water intrusion. This causes "salinization" of groundwater negatively affecting both freshwater and terrestrial biodiversity.
- Agricultural land use, road and bridge construction activities and mining resulted in sediment loading of aquatic habitats directly or via surface runoff.
- Siltation has impacted on deposition and erosion of biotopes of perennial spring streams. Silt and sand are deposited in "khawrs" and retention reservoirs affecting survival of biodiversity.
- Chemical pollutants such as nitrogen and phosphorus and toxic pesticides, hydrocarbons from oil and heavy metals from industrial wastes including organic wastes from sewage and septage disposal all contributed in the devastation of aquatic biodiversity.
- Litter, tar balls and coastal roads are most conspicuous threats to shore land environments. Small beaches in the Khasab area and along the north coast of the peninsula are staging posts for Iranian small boat traders. These beaches are severely littered with tins, bottles, glass, plastic bags, cartons and sand bags used as ballast, a matter that destroy the eco-tourism industry.

CHAPTER 4

The State of Use of Biodiversity for Food and Agriculture

The following are state of use of biodiversity for food and agriculture in respect of different sectors.

Livestock:

The state of In Situ managements

In Situ conservation and management of AnGR in the country are carried out by Ministry of Agriculture and Fisheries (MAF) and Minister of Environment and Climatic Affairs (MECA). MAF is concentrating on the conservation and management of indigenous species whereas MECA has reserved areas in different part of the country with aim of conserving the ecosystems.

Animal genetic resource surveys

MoA started a comprehensive survey for different species and breeds in the country. This survey started in the 1990's. In 2002 another survey was carried out in cooperation with FAO which focused on classification and characterization of the breeds within animal species. A special program started on 2004 to classify and characterize the small ruminant breeds in Northern part of Oman and it will last until 2014.

Conservation of AnGR in protected areas

In Oman, there exist protected areas under the MoA in Dhofar (southern Oman). The MoA monitoring these areas to develop maintain and conserve the breeds. It was determined the breeds which are in dangers. Only Dhofari goat and the local poultry breeds are defined as breeds at risk.

On-form management and improvement of AnGR.

There exist numerous activities towards conservation of local breeds in different species, through on-form management since early 1990's. In case of cows and small rumens, MoA takes responsibilities to do genetic improvement in different research centers and stations using a reliable selection program. Then distribute the selected improved rams to the farmers and small holders to improve their flocks. However, there is a need for extending such activities towards improving indigenous breeds of AnGR.

The state of Ex Situ management

The state of collections and conservations

- MAF collected AnGR in Northern Oman and in Dhofar with countless of local poultry breeds and sheep, goats and cows breeds.
- Workshop has been held in Oman for sustainable development of the agriculture sector and the organization of labor market in which institutions and government bodies and NGO's involved in governments during 10-12 February, 2007.
- In 2008, a representative of Oman has been attended in Egypt a workshop for animal genetic resources in the Near East region, which hold under the auspices of ICARDA.
- MAF started a program to conserve AnGR *Ex Situ* by establishing an international artificial insemination laboratory in the Animal Production Research Center with the aim of collecting and preservation of semen of local cattle in order to maintain it through the establishment of a National Gene Bank of AnGR.

It should be noted that what has been collected from animal genetic resources is limited and in order to ensure the conservation and sustainable use of the animal genetic resources will require a national plan of action and clearly defined mechanisms to collect the rest of animal genetic resources outside its origin to cover all of the various strains for all animal species found in Oman.

Forests:

Aquaculture & Fisheries:

Crops:

Oman has many indigenous PGRFA which are found valuable and important from economic and social point of view. These indigenous PGRFA have been found important in terms of the following:

1. Use of biotic (diseases and pests) and abiotic (salinity, drought etc.) resistant/ tolerant rootstocks with local fruit crops cultivars for multiplication and distribution among the farmers.
2. Improvement of local cultivars of wheat and barley through breeding programs using high yielding, disease resistant and early to medium maturity characteristics from exotic cultivars used as donors.
3. Improvement of indigenous lime for tolerance to diseases like witches broom through breeding program using the techniques of biotechnology and tissue culture.
4. Improvement of local date palm cultivars for their quality through breeding program using the techniques of biotechnology and tissue culture.
5. Use of indigenous perennial forage grass species in the grass production systems.

Utilization of genetic resources and major constraints on their use

Oman has initiated utilization of PGRFA in different crops through characterization, selection, and improvement using the tools of breeding and biotechnology (tissue culture). However, there exist certain constraints that are making the progress slow. These constraints are related to-

1. Documentation - useful information on the conserved germplasm
2. Infrastructure in the fields of plant breeding and biotechnology
3. Capacity- qualified personnel, funds, training, facilities etc.
4. Integration between conservation and utilization programs
5. Coordination among researchers, breeders, genebank managers and farmers

Utilization activities

Research activities on utilization of indigenous plant genetic resources are being carried out mainly by the Ministry of Agriculture and Fisheries, the Ministry of Environment and Climatic Affairs, the Ministry of Heritage and Culture, and the Sultan Qaboos University.

Characterization

Morphological Characterization

The studies on characterization of species / accessions are being conducted since 2001-2002 at the Seed and Plant Genetic Resources Lab, Plant Production Research Center, Rumais of Ministry of Agriculture and Fisheries, Sultanate of Oman. During 2001-02, two cultivars of *Cenchrus ciliaris* L. viz. an indigenous collection and Australian variety were characterized with respect to as many as 15 pigmentation characters and 7 morphological traits. *Coelachyrum piercei*was characterized in respect of 12 pigmentation characters and 8 morphological traits (Nadaf *et al.,* 2002). Investigations on the characterization of two perennial rangeland forage species namely *Lasiurus hirsutus* L. (Buraimi accession) and *Panicum turgidum* L. (Buraimi and Izki accessions) were further undertaken during 2002-2003. The Buraimi accession of *L. hirsutus* L was characterized with respect to 19 pigmentation characters and 8 morphological traits while the two accessions (Buraimi and Izki) of *P. turgidum* L. were characterized with respect to 19 pigmentation characters and 11 morphological traits Nadaf *et al.* (2003). During 2003-2004, the results of investigations have established distinct descriptors of three perennial rangeland forage species namely *L. hirsutus* L. (Mahara accession), *P. turgidum* L. (Mahara accession) and *Pennisetum divisum* (Mahara accession) with respect to morphological and pigmentation characters.The accession of *L. hirsutus* L was

characterized with respect to 19 pigmentation characters and 8 morphological traits.The accessions of of *P. turgidum* L. and *P divisum L.* were characterized with respect to 19 pigmentation characters and 11 morphological traits (Nadaf *et al.*, 2004 b). Further, six indigenous accessions of *C. ciliaris* viz. MF 179, MF 185, MF 190, MF 192, MF 236 and MF 266 collected during 1998 ICARDA-Arabian Peninsula Research Program (APRP)-MAF joint collection missions, were also subjected for morphological characterization during 2004-2005 with respect to both pigmentation and morphological traits (MAF, 2005b). Besides above, Jaradat *et al.* (2004a and 2006), Al Khanjari (2005) and Al-Rawahi (2008) characterized indigenous Omani barley, wheat and cucumber landraces, respectively. The legume germplasm accessions of the crops like alfalfa, cowpea, faba bean, field peas, mug bean, chickpea, and fenugreek collected under joint MAF-SQU mission during 2008-2010 have been subjected for utilization for characterization and quality studies by SQU and MAF research staff under post graduate programs leading to MSC and PhD degrees .

Screening for tolerance to abiotic stresses

There are no studies on screening for tolerance of PGRFA to abiotic stresses like heat, and moisture stress. However, a few studies conducted in the past seven years were concerned with tolerance to salinity in rangelands. Saline tolerant indigenous rangeland grass species are valuable either for reseeding in the degraded rangelands at corresponding salinity sites or testing/ breeding for their suitability under existing forage production system in the areas affected by salinity (Nadaf *et al.*, 2006). The legume germplasm accessions of the crops like alfalfa, cowpea, faba bean, field peas, mung bean, chickpea, and fenugreek collected under joint MAF-SQU mission during 2008-2010 have been subjected for utilization for screening for drought and salinity tolerance by SQU and MAF research staff under post graduate programs leading to MSC and PhD degrees.

Molecular characterization

Date palm

DNA profiling of six indigenous cultivars was accomplished by using RAPD and AFLP analysis. Both methods showed potentialities for fingerprinting in revealing genetic variation among the cultivars (MAF, 2005a). Molecular technology can assist plant breeder in selecting/ improving indigenous cultivar of datepalm. For this purpose, the DNA of the backcross 1 (BC1) population (55 palms) from Khalas, the local cultivar, and of their parents were analyzed using the AFLP technique (MAF, 2005a).

Genetic diversity among 16 genotypes of date palm (Phoenix dactylifera L.) from Saudi Arabia, Bahrain, Oman and Kuwait was investigatedusing 12 microsatellites (SSRs) markers in 2010-2011 under ICARDA-GCC project (MAF, 2011) . The Polymorphic Information Content (PIC) was ranged from 0.555 to 0.912 with an average of 0.77. A dendrogram was generated based on Un-weighted Pair Group Method for the Arithmetic Average (UPGMA), which showed three main clusters. Cluster one was composed of two Omani genotypes, Khalas (Ks-O6 and Ks- O11) and Khasab (Kb-O15 and Kb-O35). The second cluster was composed of Khalas genotype from Saudi Arabia(Ks-Ks3 and Ks-Ks4), Bahrain (Ks-I3 and Ks- G3) and Kuwait (Ks-Kl6) which revealed a high exchange of date palm germplasm between these countries. All the remaining genotypes (Khasab, Hilali, and Berhi) from Saudi Arabia, Bahrain and Kuwait respectively were included in the third cluster with different similarity.

Genetic diversity in date palm germplasm from Oman representing 13 cultivars was investigated in 2010-2011 using 13 microsatellite (SSR) primers. A total of 146 alleles with an average of 5.5 alleles per locus were scored. NTSYS-PC program ver. 2.20r was used to measure the degree of similarities and differences among the cultivars. The cultivars were separated into two main clusters. Different level of heterozygosity was observed among the studied cultivars.

Eighty seven date palms were used for the purpose of genetic linkage mapping analysis in 2012. Fifty-three palms were from a BC1 population and the other 34 palms were F1 populations. The two populations were developed using the same male (Kl-96-13) and two different females Khalas 4 and Um-Alsela. The DNA samples from two populations (BC1 and F1) were analyzed using seventy-six microsatellite (SSR) primer pairs.

Alfalfa

Al-Hinai (2004) characterized local alfalfa accessions using morpho-agronomic traits such as plant height, number of branches, number of leaves per plant, fresh and dry matter weight, regrowth rate and molecular markers by utilizing genomic Random Amplified Polymorphic DNA (RAPD) technique. The studies have been initiated in 2012 for biochemical characterization of 40 indigenous accessions under post graduate degree program through the AFDF research budget.

Crop improvement programs and food security

First plant breeding program started in 2001. This breeding program was directed in improving local landraces of wheat and barley. During the coming decade, breeding programs may also focus on vegetable crops such as cucumber, as well as carrots, onions, garlic, and muskmelons, and forage species such as alfalfa.

Wheat and Barley

The wheat and baley breeding programs which started in 2001 and 2008, respectively, were aimed at improving local landraces of wheat by introgression of early maturity and disease resistance traits from exotic cultivars obtained through international research programssuch as ICARDA and CIMMYT. Pedigree method of breeding was applied to introduced materials, which showed stable high yielding performance and early maturity in the wheat and bar;ley growing areas of Oman. (MAF, 2004b and 2005b and MAF 2012). Incorporating early maturity trait to the late maturing local landraces was very important. By shortening the growing season of wheat this trait allowed to escape high temperatures that coincide with maturity time and reduce assimilate accumulation in the grains, as well as to save irrigation water otherwise required to complete the crop cycle. Four improved early versions of local wheat cultivars viz. Cooley and Sarraya were developed from four crosses Cooley x WQS 302, Cooley X WQS 125, Sarraya x WQS 302 and Sarraya x WQS 125, respectively with popular names as Nizwa, Jibreen, Nezd and Bahla and have been recommended to release for general cultivation in the country. Advanced breeding lines of barley are in F_4 stage.

Date palm

Activities in data palm has mainly focused on maintaining the genetic diversity as well as for developing new strains with desired traits. Cultivar Khalas was backcrossed with a male that was produced from seeds of the same cultivar. Seeds from this cross were planted to produce BC_1population. BC_1 female palms that reached flowering were pollinated and their fruits evaluated for quality. Six date palms out of 16 evaluated were superior in yield and fruit quality to the original cultivar Khalas (MAF, 2005b). The most common cultivar in the Batinah governorate, Um-Assela, which is saline tolerant but with low quality fruits, was crossed with the male KL96-13 (originated from cultivar Khalas) to produce an F_1 population.

Females from this cross are being evaluated for fruit quality.The results showed improvement in shape, color and size of the produced fruits (MAF, 2005b).

Variety release, Seed production, supply, and role of markets

High yielding elite genotypes are released for general cultivation based on recommendations from scientists who are involved in carrying out variety performance trials, mainly in research stations and farmers' fields in different years and

locations. MAF is responsible to enforce the law of plant variety protection and carrying out Distinctness, Uniformity, and Stability (DUS) tests as per Royal Decree 92/2000.

Seed Production and Supply

In the Sultanate, the national seed program has not yet been fully developed. Seed production was started in 1979 under the direct supervision of agricultural research stations and initially restricted to Al'Dakhliya area.The program was later expanded to cover Al'Sharqiya and Al'Dharhira and become under the direct supervision of the extension service.

The Government undertakes the responsibility of seed production, particularly of some major crops such as wheat and barley. Breeder (by ear to row method) and foundation seed of recommended varieties are maintained and multiplied at selected agricultural research stations.

The foundation seed is supplied to the agricultural extension service, which produces certified seed of wheat and barley involving farmers. The seed of other crops is multiplied on a limited scale at agricultural research stations. The seed is produced under the direct supervision of the extension service, and a research-extension committee monitors the program.

The extension service is responsible for the selection of contract farmers; provision of seed, fertilizers, plant protection services; technical backstopping and supervision; and financial support for roguing seed crops. It also provides seed bags and purchases seed at premium price, which is treated and stored until distribution. The farmer provides the land and irrigation and is responsible for general cultivation and harvesting of seed crops.

Most farmers produce their own alfalfa seed. Generally, the seed is harvested from the crop when this is 4-5 years old. This practice of harvesting seed from old stands applies a strong selection pressure in favor of those plants, which have survived several years of cutting. It will tend to ensure that these important 'survival' characteristics are preserved and enhanced in successive multiplication. This may explain in part the widespread reputation of the alfalfa variety known as 'Omani' in the country.

As per vegetables, a rather limited seed production of local cultivars of onion, garlic, carrot, cucumber, muskmelon, and sweet potato is carried out by farmers. Apart from these scattered efforts, there is not an organized local seed production program either by the Government or by the private sector. Several international seed companies have branches in the country in association with local seed companies or agents. These companies import seed of promising varieties from USA, Australia, the Middle East, Asia, Africa and European countries and supply the seed either directly to the farmers or through the Government.

Research studies have been conducted for large-scale seed production of indigenous pasture species for their inclusion in the domestic grass production system (Nadaf *et al.*, 2004 a). Other studies addressed agronomic and seed harvesting techniques (Nadaf *et al.*, 2004 c, d and e).

Seed Processing and Storage

Seed processing is carried out by the agricultural extension services in different locations with the limited facilities available for crops like wheat and barley. After cleaning, seed is bagged, fumigated and stored in temporary facilities at the offices at Ibra, Ibri and Nizwa of the Ministry of Agriculture & Fisheries under the supervision of Directorate Generals of the governorates.

Seed Marketing and Distribution

Wheat and barley seeds are distributed to interested farmers free of cost while seeds for other crops like vegetables, perennial forages, etc. have to be purchased by farmers from various companies that import seed for sale. Besides,

some farmers sell their own seed of indigenous vegetables in the local market.

Seed Quality Control

Seed quality control consists mostly of purity and germination tests, which are carried out both for locally produced and imported seeds, before distribution to the farmers. The Seed and Plant Genetic Resources Laboratory conducts tests for purity and germination samples of locally produced wheat and barley seed, as well as of imported seed of perennial grasses and vegetables. At present, this is the only laboratory, which operates both for locally produced and/or imported seed.

Seed Import/Export

Agricultural companies that have valid permits issued by the Ministry of Commerce and Industry, import the seed of mainly vegetables and perennial forages like Rhodes grass and grafted seedlings/scions/rootstocks of fruit trees from companies in Africa, Asia, Australia, Middle East, Europe, and USA. The Ministry of Agriculture and Fisheries issues licenses for companies importing particular seed material.

At present, there is no specific seed law to control seed import except the quarantine regulations of the Law of Agriculture Quarantine (Royal Decree No. 49/77) concerning nursery plant and seed material. However, the new Law on Agriculture (Royal decree No. 48/2006) that will be enforced in near future includes a specific chapter covering all seed-related aspects. There are quarantine centers both at the airport and at entry borders to enforce the regulations. The Ministry of Agriculture and Fisheries and Royal Oman Police enforce the quarantine law.

Major Needs to improve utilization

The following are assessed as needs to improve the activities of utilization:

1. Identification of the crops and their indigenous landraces and nature of utilization such as finding indigenous landraces tolerant to witches broom in lime, dubas bug in date-palms, mango decline in mango and salinity in field, vegetable and forage crops for sustainable development in agriculture.
2. To take steps in avoiding duplication of activities in utilization of plant genetic resources for food and agriculture among the stakeholders.
3. Increase capacity of the stakeholders in the field of PGRFA through academic and in-service training programs.
4. Collaboration with agricultural private sectors to develop a national project and plan of action for breeding and seed production of PGRFA.

CHAPTER 5
The State of Interventions on Conservation and Use of Biodiversity for Food and Agriculture

Oman adopted in 2001 the National Biodiversity Strategy and Action Plan (NBSAP), as a reference document in order to stick to commitments accepted with the ratification of the Convention on Biological Diversity. The National Strategy illustrates the political directions as well as the basic rules, principles andguidelines which the Sultanate can use to direct the development process hand in handwith the preservation of biodiversity to contribute in achieving the biodiversity objectives of the National Strategy that includes nine main objectives:

1. Protection of natural habitats and productive, renewable resources for rational and sustainable utilization.
2. Conservation of natural habitat environments and the biodiversity of fauna and flora, particularly rare species and those of special significance.
3. Providing a high-quality natural environment for recreational and touristic activities.
4. Improvement of knowledge on ecosystems and elevation of resource management capabilities.
5. Raising awareness on the importance of biodiversity conservation and the sustainable use of biological resources.
6. Passing legislation to ensure biodiversity conservation and the sustainable use of biological resources.
7. Building a system of incentives to encourage the activities of biodiversity conservation and the creation of job opportunities for the locals.
8. Equal distribution of the returns yielded from the sustainable use of resources at the local and regional levels, including genetic resources.
9. Promoting regional and international cooperation in the fields of biodiversity conservation and the sustainable use of natural resources.

The NBSAP of Oman aims to merge and integrate biodiversity conservation targets and sustainable use of natural resources within sectorial policies, and as a consequence the implementation of the **vision** of the updated national strategy itself in 2013: "To work together rationally for reconciliation and harmonization with Nature".

For instance and in accordance with the strategic plan for the sustainable development of the country, the national strategy provides for the execution of a number of priority objectives, including:

1. Assessment of the status of biological diversity and its value.
2. Identification and reduction of threats to species and ecosystems mainly from human activities.
3. Establishing traditional but wise dependence of local communities on the conservation and sustainable use of biodiversity, including agricultural biodiversity to meet the population's needs for food, health care, fuel, construction materials, raw materials, commercial, industrial, recreational and a variety of other resources.
4. Enlightening the best conditions for environment recovery and reducing of greenhouse effects due to the increase of CO2 (carbon emissions) for the conservation of biological diversity.
5. Development of the legal framework for the protection of biological resources, determining the balance between economic and social environmental benefits for the sustainable use of biological resources at the regional national and local levels.

6. Improvement of the system of coordination of actions aimed to resolve biodiversity issues.
7. Restoration of habitats and ecosystems.
8. Raising awareness and education of the local population and public.
9. Undertaking inventories of all fields as available to classify economic, ecological, and sensitive species, as well as ecosystems and habitats of interests.
10. Richness of genetic diversity for the development of sustainable cultivars and breeds of domestic animals.
11. Improving legal and economic conditions for biodiversity conservation.

However, this national strategy, developed in 2001, as a policy document, supported by public funding and binding for execution, was approved by the government. Many of the provisions of the National Strategy and the Action Plan on the conservation and sustainable use of biodiversity in Oman relate to different ministries and agencies, not subordinate to the Ministry of Regional Municipalities, Environment & Water Resources (now - the Ministry of Environment and Climate Affairs), therefore the provisions of this document tend to be slightly better reflected in sectorial plans.

In accordance with resolutions adopted at the 10th and 11th Conferences of the Parties on the conservation of biological diversity, currently a new National Biodiversity Strategy is about to be finalized, primarily with support of the government of Oman, and the technical support of UNEP. The strategy was submitted for approval during 2014.

In general, the current Oman's interests aimed at conservation of the biodiversity, coupled with the improvement of people's lives, should resolve issues of biodiversity and prevention of desertification and land degradation; rehabilitation of ecological disaster areas (chiefly, Mangrove); prevention of pollution of the sea; prevention of pollution and depletion of water resources; prevention of air pollution, bacteriological and chemical contamination; reduction of volumes of industrial and domestic wastes; and prevention of natural and manmade emergencies.

Livestock:

National Programs, Legislation and Property Rights for developing Animal Genetic Resources

The government, in more than anything else, enacts legislation and issues the regulations related to the development and maintenance of AnGR.

National Program:
MAF carries out AnGR development programs like the national research program for selection, crossing and AI (artificial insemination) programs to improve the productivity of the local breed of cows, sheep, goats and poultry. Furthermore, such programs can increase the genetic progress and selection.

Training and capacity building:
The government contributes greatly to develop the infrastructure and capacity building through the national university graduation and missions sent abroad. The government contributes to the extension and support services to improve the technical level for the local cadre.

Legislation and property

There are legislations that regulate the utilization of AnGR and their management in what concerns veterinary quarantine and livestock entry to the country. Also, there are legislations dealing with grazing land and the management of the environment. Legislations of grazing lands and of animal wealth management are considered as the main themes in legislations regarding the utilization of AnGR. The legislations could be summarized in the following decrees:

- The Royal Decree No. 119/1994 on approving to join Oman in the biodiversity agreement,
- The Royal Decree No. 43/1996 concerning the law on the veterinary busines and opening the private
- veterinary clinics,
- The Royal Decree No. 114/2001 concerning the law on conservation of the environment and
- prevention of pollution,
- The Royal Decree No. 6/2003 related to the law on natural reserves and wildlife conservation,
- The Royal Decree No. 8/2003 on the law of rangelands and animal wealth management,
- The Royal Decree No. 45/2004 on the law ok veterinary quarantine,
- The Royal Decree No. 48/2004 on setting up the agriculture and fisheries developmental funds,
- The Royal Decree No. 48/2006 on law of agriculture.

Forests:

Aquaculture & Fisheries:

Crops:

The State of National Programs, Training and Legislation

National programs

A number of institutions and organizations directly or indirectly contribute to the conservation and sustainable utilization of PGRFA in the Sultanate. These include the Directorate General of Agricultural and Livestock Research and the Directorate General of Agriculture Development from the Ministry of Agriculture and Fisheries, Directorate General of Nature Conservation from the Ministry of Environment and Climate Affairs, the Department of Crop Sciences, College of Agricultural and Marine Sciences, Sultan Qaboos University and Diwan of Royal Court.

Significant results have been achieved by these stakeholders, as they play key roles for the conservation and sustainable utilization of PGRFA in the country. This has occurred despite absence of formal PGRFA program, coordinating and integrating the activities carried out by national stakeholders, until December 2007 when two committees on PGRFA were established- the steering committee and the technical committee. With the aims to exchange information, assess the state of PGRFA through participatory approach and, *inter alia*, build stronger partnerships among stakeholders, a National Information-Sharing Mechanism on PGRFA has been established in 2007 by the Ministry of Agriculture and Fisheries under the coordination of the Directorate General of Agricultural and Livestock Research, and the participation of several national stakeholders, including the Directorate General of Agricultural Development; Ministry of Agriculture and Fisheries, the Ministry of Environment and Climatic Affairs, the College of Agricultural and Marine Sciences; Sultan Qaboos University and the Royal Court Affairs. Through this Mechanism, stakeholders have recognized the need to establish a multi-stakeholders National Program for PGRFA, which efficiently increases services' delivery to farmers and promotes farmers' role in the country in PGRFA management and in the preservation of the environment. The Program would count on a clear mandate for PGRFA *in situ* and *ex situ* conservation, utilization, and capacity building in line with the 20 priority activities of the *Global Plan of Action on PGRFA*, harmonize roles and responsibilities of the different stakeholders, and rely on appropriate structures.

The implementation of a strong National PGRFA Program would have also positive repercussions on the role, the country plays at regional level, where it is presently engaged in drafting regional strategy for *ex- situ* conservation of the West Asia and North Africa (WANA). With the adoption and implementation of this regional strategy, Oman will have to adjust *ex situ* conservation efforts in harmony with the regionally agreed framework in order to take full advantage from it. In particular, the country will have to enhance accessibility to conserved PGRFA as well as to their information, also in the light of its commitments towards the ratified International Treaty on PGRFA

Education and Training

Training in the field of PGRFA has so far received less attention. So far, the national scientists have not been able to undertake enough education or long-term training program in plant genetic resources. However, some short courses were held by national staff addressing existing *ex situ* collection, regenerating threatened *ex situ* accessions, expanding *ex situ* conservation activities, germplasm characterization and/or evaluation, supporting seed production and distribution, and documentation. A few nationals either graduated or post-graduated in PGRFA related subjects. Since 1996, only few scientists from the Ministry of Agriculture and Fisheries, one of the major stakeholders

of PGRFA, had the opportunity to be trained in plant breeding and germplasm characterization and/or evaluation. Post-graduate academic training is essential to build a strong national program and set the basis for a durable impact on conservation and utilization of PGRFA. More assistance in this regard needs to be provided by international organizations in future to meet the demand for training.

National Legislations

Several legislation and regulations have been issued since the past 5 years that deal with conservation and utilization of PGRFA. Most of these were issued in the form of royal decrees addressing specific issues as follows:

1. Royal Decree No. 92/2000 on the Law of Plant Variety Protection,
2. The Royal Decree No. 114/2001 concerning the Law on Conservation of the environment and Prevention of pollution,
3. The Royal Decree No. 55/2002 related to Ratification of Cartagena Protocol on Biosafety,
4. The Royal Decree No. 6/2003 related to the Law on nature reserves and wildlife conservation,
5. The Royal Decree No 8/2003 on the Law of Rangelands and Animal Wealth Management,
6. The Royal Decree No. 47/2004 on the Law of Agricultural Quarantine,
7. The Royal Decree No. 48/2004 on setting up the Agriculture and Fisheries Developmental Fund,
8. The order No. 35/2004 of Ministry of Agriculture and Fisheries on regulations for execution of the Law of Plant Variety Protection,
9. The Royal Decree No. 57/2004 concerning participation in the InternationalTreaty on Plant Genetic Resources for Food and Agriculture,
10. The Royal Decree No. 6/2006 on establishment of Oman Botanic Garden,
11. The Royal Decree No. 48/2006 on Law of Agriculture which deals with PGRFA and issues related to seed production and distribution,
12. The Royal Decree No. 86/2007 on establishment of International Plant Genetic Resources Institute (Bioversity International).
13. The Royal Decree No. 49/2009 for promulgating the law on the protection of Breeders' Rights in the new varieties of plants
14. Ministry of Agriculture and Fisheries Order No.91/2009 to formulate a committee for preparation of feasibility report to establish Specialized Center of Animal and Plant Genetic Resources.
15. Ministerial Decision of Ministry of Agriculture & Fisheries No. 29/2012 about establishment of committee to study and revise the national strategy on date palm development.

Additional Royal decrees were issued earlier concerning international issues of conservation and utilization of PGRFA, which are the ratification of the *Convention of Biological Diversity* (Royal Decree No. 119/1994) and the ratification of the *Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture* (Royal decree No. 10/1997).

The implementation of these laws and regulations need to be monitored effectively to have positive impacts on the conservation and utilization of plant genetic resources for food and agriculture, and to take advantage of opportunities that arise with them.

Information systems

As part of the establishment of the National Information Sharing Mechanism on plant genetic resource for food and agriculture in Oman, a database on PGRFA was developed with information contributed by major national stakeholders. This database includes information on organizations, experts, and projects that deal with *in situ* and *ex situ* conservation as well as utilization of PGRFA. It also includes a comprehensive list of taxa, varieties cultivated in the country, and PGRFA related publications. The database can be accessed through the internet since July 2007 at http://www.pgrfa.org/gpa/omn.

Plans to establish an accession level information management system to support plant gene bank management and breeding activities are on-going. Recently, the Ministry of Agriculture and Fisheries with assistance of Bioversity International (former IPGRI) is developed a database management system, the Genetic Resources Modeling System (GeRMS).The system is expected to help the newly established National Gene Bank in managing germplasm accessions. This system should provide stakeholders with access to information on accessions conserved at the Seed and Plant Genetic Resources Unit through the internet.

Public awareness

There have been several efforts from different governmental sectors to make public aware about the importance of plant genetic resources of the country. Recent Ministerial Order No. 203/2007 of the Ministry of Agriculture and Fisheries would expectedly enhance the public awareness about diversified issues of plant genetic resources through implementing its activities.

CHAPTER 6

Future Agendas for Conservation and Sustainable Use of Biodiversity for Food and Agriculture

The state of diversity in the country could be improved by applying the following measurements: i.). Encouraging and supporting research and developmental programs concerning plant genetic resources of the country and benefiting from the expertise and experiences of the international organizations and research institutes. ii).Capacity building in terms of improving qualifications and on-job training of the concerned staff. Iii). Implementing awareness program on the importance of conservation of indigenous biodiversity. Activating Royal Decrees and Ministerial Orders, and iv). Executing rules and regulations related to conservation of biodiversity..

Major Ex Situ needs

Ex situ management needs to be improved. The way to improve it inevitably passes through the development of a national concerted strategy for the conservation and sustainable use of biodiversity and a National Program to implement it. The national strategy and its program should help to improve the efficiency of our activities in biodiversity by reducing duplicative efforts and making more human and financial resources available for fostering agricultural development through a more sustainable use of biodiversity. All biodiversity stakeholders in Oman need to contribute jointly to the development of this strategy and to formulate objectives, themes and mechanisms of the National Program. In this connection, experience of other countries as well as international organizations and institutes that have established their own programs may be explored.

Major Needs to improve utilization

The following are assessed as needs to improve the activities of utilization:

- Identification of the crops and their indigenous landraces and nature of utilization such as finding indigenous landraces tolerant to witches broom in lime, dubas bug in date-palms, mango decline in mango and salinity in field, vegetable and forage crops for sustainable development in agriculture.
- To take steps in avoiding duplication of activities in utilization of plant genetic resources for food and agriculture among the stakeholders.
- Increase capacity of the stakeholders in the field of biodiversity through academic and in-service training programs.
- Collaboration with agricultural private sectors to develop a national project and plan of action for breeding and seed production of biodiversity.

Major needs for public awareness of biodiversity

- There is a need to activate national program related to activities of bidiversity.
- There is need for capacity building of national scientists in the conservation and utilization of biodiversity.
- Implementation of the laws and regulations related to conservation and utilization of biodiversity need to be monitored effectively to have positive impacts on the conservation and utilization of biodiversity for food and agriculture.
- There is a need for the expansion of public awareness.
- There is a need for effective gathering of indigenous knowledge on biodiversity..

REFERENCES

Al-Hinai. S.A. 2004. Study of genetic variations in local germplasm of alfalfa (Medicago sativa L.) using random amplified polymorphic DNA (RAPD) technique. M.Sc.Thesis submitted to Sultan Qaboos University. 88p.

Al Khanjari, S. 2005. Exploration and estimation of morphological and genetic diversity of wheat (Triticum spp.) landraces in Oman. Ph.D Dissertation submitted to Kassel University. Germany. 138 p.

Al-Khanjari, S., Hammer, K., Buerkert, A., Khan, I. and Al-Maskri, A. 2005. A survey of wheat landraces in Oman. *Plant Genetic Resources Newsletter* 141: 10-1.

Al-Rawahi, M.S. 2008. Morphological and genetic diversity of cucumber land races in Oman. M.Sc.Thesis submitted to the Sultan Qaboos University. 112p.

Al-Zidjali, T. M. 1996. Oman- Country Report. FAO International Technical Conference on plant genetic resources, held at Leipzig, Germany from 17-23 June 1996.

Anonymous. 2007. Country Report on the State of Animal Genetic Resources In the Sultanate of Oman.

Ferguson, M. 1999. Report on collection of rangeland plant germplasm in the Sultanate of Oman in March-April, 1998. Presented in the ICARDA-APRP Meeting held at Muscat in June, 1999.

Ghazanfar, S.A., Miller, A.G., Mc Leish, I., Cope,T.A., Cribb, P. and Al-Rawahi, S.H. 1995. Plant Conservation in Oman. Part-I. A study of the endemic, regionally endemic and threatened plants of the Sultanate of Oman. April 1995. 15 p. Sultan Qaboos University, Oman.

Guarino, L. 1989. Barley collecting in southern Arabia. FAO/IBPGR. Plant Genet. Resour. Newsl. 73:34-36.

Guarino, L. 1990. Crop collecting in the Sultanate of Oamn in the context of the Arabian Peninsula. FAO/IBPGR. Plant Genet. Resour. Newsl. 77:27-33.

Jaradat, A.A. and Shahid, M. 2006. Population and multilocus isozyme structures in barley landrace. *Plant genetic resources:Characterization and utilization.4: 108-116.*

Jaradat, A.A., Shahid, M. and Al-Maskri, A. 2004 a. Genetic diversity in Batini barley land race from Oman:I. Spike and seed quantitative and qualitative traits. *Crop Sci. 44:* 304-315.

Jaradat, A.A., Shahid, M. and Al-Maskri, A. 2004 b. Genetic diversity in Batini barley land race from Oman:II. Response to salinity stress. *Crop Sci. 44:* 997-1007.

Jaradat,A.A., Shahid, M. and Al-Maskri,A. 2005. Biomass production potential in the Batini barley landrace from Oman. J. Food, Agriculture and Environment. 3: 249-253.

MAF.2004 a. Agriculture Statistics-2004. Directorate of Agriculture Statistics. Ministry of Agriculture & Fisheries. Sultanate of Oman.

MAF. 2004 b.Annual Report of Agriculture Research-2003-2004 (Abstracts). Directorate of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries. Sultanate of Oman.

MAF. 2005a. Agriculture Census 2004/2005. Department of Statistics and Information. Ministry of Agriculture and Fisheries. Sultanate of Oman.

MAF 2005b. Morphological characterization of six indigenous accessions of *Cenchrus ciliaris L*. Annual Report of Agriculture Research-2005 (Abstracts). Directorate of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries. Sultanate of Oman (Arabic).

MAF 2005c. Establishment of field genebank of indigenous medicinal plant species of Oman. Annual Report of Agriculture Research-2003-2004 (Abstracts). Directorate of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries. Sultanate of Oman. Pp 24-25 (Arabic).

MAF. (2007). Agriculture and Livestock Research Annual Report - 2007. Directorate General of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries, Sultanate of Oman.

MAF. (2009). Agriculture and Livestock Research Annual Report - 2009. Directorate General of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries, Sultanate of Oman.

MAF. (2010). Agriculture and Livestock Research Annual Report - 2010. Directorate General of Agriculture and Livestock Research. Ministry of Agriculture and Fisheries, Sultanate of Oman.

MAF. 2011. Agricultural and Fisheries Statistical Year Book. Ministry of Agriculture & Fisheries. Sultanate of Oman. 109 p.

MAF. 2012. The State of Animal Genetic Resources in Oman. Ministry of Agriculture & Fisheries. Sultanate of Oman.

MAF. 2014. Agricultural and Fisheries Statistical Year Book. Ministry of Agriculture & Fisheries. Sultanate of Oman.

MECA. 2014. 5th National Report to CBD. Ministry of Environment and Climate Affairs. Sultanate of Oman.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A. 2002. Morphological characterization of two rangeland grass species.Annual Report 2001/2002. Arabian Peninsula Research Program (APRP). Presented in ICARDA-APRP Annual Meeting held in Yemen. 28 September -2 October 2002. Annual Report 2001/2002. pp. 107-109.

Nadaf, S.K.,Al-Farsi, S.M. and Al-Hinai, S.A. 2003. Morphological characterization of two rangeland grass species.Annual Report 2001/2002. Arabian Peninsula Research Program (APRP). Presented in ICARDA-APRP Annual Meeting held in Syria. December. 2003. Annual Report 2002/2003. Pp. 92-93.

Nadaf, S.K. Al-Farsi, S.M. and Al-Hinai, S.A. 2004 a. Seed production of indigenous rangeland forage species in Oman. *Seed Info*. 2004. 27: 12-14.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A. 2004 b. Morphological characterization of three rangeland grass species. Presented in ICARDA-APRP Annual Meeting held in Muscat. February 2005. Annual Report 2003/2004. Pp.130- 132.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A. 2004 c. Effect of inter-row and inter-plant spacing on seed yield and its related traits of indigenous rangeland and forage grass species grown under drips and sprinklers. Presented in ICARDA-APRP Annual Meeting held in Muscat. February 2005. Annual Report 2003/2004. Pp.104-108.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A. 2004 d. Effect of maturity stage on seed weight *per se* and seed quality in indigenous rangeland and forage grass species. Presented in ICARDA-APRP Annual Meeting held in Muscat. February 2005. Annual Report 2003/2004. Pp.109-120.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A. 2004 e. Influence of early and late forming tillers on seed weight *per se* and seed quality in indigenous rangeland and forage grass species. Presented in ICARDA-APRP Annual Meeting held in Muscat. February 2005. Annual Report 2003/2004. Pp.121-129.

Nadaf, S.K., Al-Farsi, S.M. and Al-Hinai, S.A., Al-Bakri, A.N and Al-Harthy, A.S. 2004 f. Establishment of field genebank of indigenous pasture plant species of Oman. Presented in ICARDA-APRP Annual Meeting held in Muscat. February 2005. Annual Report 2003/2004. Pp.73-82.

Nadaf, S.K. Al-Farsi, S.M. and Al-Hinai, S.A. Al-Khamisi, S.A., Al-Bakri, A. N and Al-Lawati, A.H. 2006. Response of Indigenous Rangeland and Cultivated Forage Species to Salinity. I. Agronomic attributes. Agri. & Fish. Res. Bulletin of Ministry of Agriculture & Fisheries, Sultanate of Oman.Vol 1, No.8.21-51.

NCSR (National Center for Statistics and Information). 2012. Statistical Year Book. Sultanate Oman.

NSSDAR. 2012. Report of National Strategy of sustainable development for animal resources. Ministry of Agriculture & Fisheries. Sutanate of Oman.

Osman, Ahmed., Nadaf, S.K., Al-Farsi,S. M. and Al-Hinai, S.A. 2002. Forage and range germplasm collection in Dhofar, Oman. Arabian Peninsula Research Program (APRP). Presented in ICARDA-APRP Annual Meeting held inYemen. 28 September -2 October 2002. Annual Report 2001/2002. pp. 103-106.

ACRONYMS

AnGR	Animal Genetic Resources
AqGR	Aquatic Genetic Resources
CBD	Convention on Biological Diversity
CGIAR	The Consultative Group for International Agricultural Research
DGALR	Directorate General of Agriculture & Livestock Research
DRC	Diwan of Royal Court, Oman
FAO	Food & Agriculture Organization of United Nations
FGR	Forest Genetic Resources
GeRMS	Genetic Resources Modeling System
ICARDA`	International Center for Agricultural Research in the Dry Areas, Syria
ICBA	International Center for Biosaline Agriculture, Dubai
ITPGRFA	International Treaty of Plant Genetic Resources for Food & Agriculture
PGRFA	Plant Genetic Resources for Food & Agriculture
NABSAP	National Biodiversity Strategy and Action Plan
MAF	Ministry of Agriculture & Fisheries, Oman
MECA	Ministry of Environment & Climate Affairs, Oman
MHC	Ministry of Heritage & Culture, Oman
OAPGRC	Oman Animal & Plant Genetic Resources Center
PA	Protected Areas
RCA	Royal Court Affairs, Oman
SQU	The Sultan Qaboos University, Oman
TRC	The Research Council, Oman

ANNEX 1: Recommended scope of the Country Report

Biodiversity for food and agriculture

Biodiversity for food and agriculture includes the variety and variability of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain the ecosystem structures, functions and processes in and around production systems, and that provide food and non-food agriculture products. Production systems, as defined for the purposes of this report, include the livestock, crop, fisheries and aquaculture and forest sectors. The diversity found in and around production systems has been managed or influenced by farmers, pastoralists, forest dwellers and fisherfolk over many hundreds of generations and reflects the diversity of both human activities and natural processes.

The present Guidelines for the SoWBFA mainly focus on those areas not covered by completed or on-going Country Reports on Animal, Forest, Plant and Aquatic Genetic Resources, e.g. the biological diversity associated with different supporting and regulating ecosystem services within production systems or of importance to them, referred to hereinafter as associated biodiversity, and wild resources used for food.

Associated biodiversity

For the scope of this report, associated biodiversity comprises those species of importance to ecosystem function, for example, through pollination, control of plant, animal and aquatic pests, soil formation and health, water provision and quality, etc., including *inter alia*:

a) Micro-organisms (including bacteria, viruses and protists) and fungi in and around production systems of importance to use and production such as mycorrhizal fungi, soil microbes, planktonic microbes, and rumen microbes;

b) Invertebrates, including insects, spiders, worms, and all other invertebrates that are of importance to crop, animal, fish and forest production in different ways, including as decomposers, pests, pollinators, and predators, in and around production systems;

c) Vertebrates, including amphibians, reptiles, and wild (non-domesticated) birds and mammals, including wild relatives, of importance to crop, animal, fish and forest production as pests, predators, pollinators or in other ways, in and around production systems;

d) Wild and cultivated terrestrial and aquatic plants other than crops and crop wild relatives, in and around production areas such as hedge plants, weeds, and species present in riparian corridors, rivers, lakes and coastal marine waters that contribute indirectly to production.

Note that domesticated species may also provide ecosystem services other than provisioning ones and affect crop, animal, fish and forest production in different ways. However since these species are already addressed in other State of the World Reports, countries may choose whether or not they want to include them in their Country Reports for the SoWBFA.

Integrated analysis of biodiversity for food and agriculture

The scope of the Report builds upon the contribution of individual sector reports by providing an integrative analysis of interactions, including synergies, interlinkages and trade-offs, between genetic resources of the different sectors. This is achieved through the identification of production systems within the country (Annex 2), and particular focus upon ecosystem perspectives in relation to biodiversity for food and agriculture. Questions addressing overall biodiversity for food and agriculture target information that would build upon what may be available in previous or ongoing country reports.

ANNEX 2: Production systems

Table 1. Climatic zones definitions

Climatic zone	Definition
Tropics	All months with monthly mean temperature, corrected to sea level, above 18°C.
Subtropics	One or more months with monthly mean temperatures, corrected to sea level, below 18°C but above 5 °C.
Temperate	At least one month with monthly mean temperatures, corrected to sea level, below 5 °C and four or more months above 10 °C.
Boreal	At least one month with monthly mean temperatures, corrected to sea level, below 5 °C and more than one but less than four months above 10 °C.

Table 2. Production systems descriptions

Name of production system	Climatic zone	Description
Livestock grassland-based systems	Tropics	Systems in which the animals obtain a large proportion of their forage intake by grazing natural or sown pastures, includes: • Ranching: grassland-based systems in which livestock is kept on privately owned rangeland • Pastoralist: grassland-based systems in which the livestock keepers move with their herds or flocks in an opportunistic way on communal land to find feed and water for their animals (either from or not from a fixed home base)
	Subtropics	
	Temperate	
	Boreal and /or highlands[36]	
Livestock landless systems	Tropics	Systems in which livestock production is separated from the land where the feed given to the animals is produced.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Naturally regenerated forests	Tropics	Includes: • Primary: Forests of native species, where there are no clearly visible indications of human activities and the ecological processes are not directly disturbed by humans • modified natural: Forests of naturally regenerated native species where there are clearly visible indications of significant human activities • semi-natural (assisted natural regeneration): Silvicultural practices in natural forest by intensive management (weeding, fertilizing, thinning, selective logging)
	Subtropics	
	Temperate	
	Boreal	
	Boreal and /or highlands	
Planted forests	Tropics	Includes : • semi-natural (planted component) : Forests of native species, established through planting or seeding, intensively managed • Plantations (productive) : Forests of introduced and/or native species established through planting or seeding mainly for production of wood or non-wood goods
	Subtropics	
	Temperate	
	Boreal	

[36] High elevation montane environments where climate differs significantly from surrounding lower elevation areas, including alpine and sub-alpine zones, tropical highlands, dryland mountains, etc.

	Boreal and /or highlands	• Plantations (protective) : Forests of introduced and/or native species, established through planting or seeding mainly for provision of services
Self-recruiting capture fisheries	Tropics	Includes capture fisheries in marine, coastal and inland areas that can involve • Natural ecosystems • Modified ecosystems e.g. reservoirs and rice paddies;
	Subtropics	
	Temperate	
	Boreal	
Culture-based fisheries	Tropics	Fisheries on resources, the recruitment of which originates or is supplemented from cultured stocks (i.e., populations chosen for culture and not stocks in the same sense as that term is used for capture fisheries) raising total production beyond the level sustainable through natural processes.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Fed aquaculture	Tropics	The farming of aquatic organisms including fish, mollusks, crustaceans, aquatic plants, crocodiles, alligators, turtles and amphibians. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc. Farming also implies individual or corporate ownership of the stock being cultivated; i.e., the population chosen for culture and not a stock in the same sense as that term is used for capture fisheries. Fed aquaculture production utilizes or has the potential to utilize aquafeeds of any type in contrast with the farming of filter-feeding invertebrates and aquatic plants that relies exclusively on natural productivity. Also defined as “farming of aquatic organisms utilizing aquafeeds in contrast to that deriving nutrition directly from nature”.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Non-Fed aquaculture	Tropics	The farming of aquatic organisms including fish, mollusks, crustaceans, aquatic plants that do not need supplemental feeding. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc. Farming also implies individual or corporate ownership of the stock being cultivated; i.e., the population chosen for culture and not a stock in the same sense as that term is used for capture fisheries. In non-fed aquaculture systems culture is predominately dependent on the natural environment for food, e.g. aquatic plants and mollusks.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Irrigated crops (rice)	Tropics	Irrigated rice refers to areas where rice is cultivated purposely provided with water, including land irrigated by controlled flooding.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Irrigated crops (other)	Tropics	Irrigated crops other than rice refers to agricultural areas purposely provided with water, including land irrigated by controlled flooding.
	Subtropics	
	Temperate	
	Boreal and /or highlands	
Rainfed crops	Tropics	Agricultural practice relying exclusively on rainfall as its source of water.
	Subtropics	
	Temperate	
	Boreal and /or	

	highlands	
Mixed production systems (livestock, crop, forest and /or aquatic and fisheries mixed)	Tropics	Production systems with multiple components. They include: • Crop-livestock: mixed systems in which livestock production is integrated with crop production. • Agro-pastoralist: livestock-oriented systems that involve some crop production in addition to keeping grazing livestock on rangelands; they may involve migration with the livestock away from the cropland for part of the year; in some areas, agropastoral systems emerged from pastoral systems • Agroforestry-livestock: mixed system in which livestock production is integrated with the production of trees and shrubs[38] • Integrated aquaculture: mixed systems in which aquaculture is integrated with crop and livestock production. May involve ponds on farms, flooded fields, enrichment of ponds with organic waste, etc. • Other combinations

ANNEX 3: Drivers of change

Table 1. Drivers of change and descriptions.

Drivers	Description, Subcategories and Examples
Changes in land and water use and management	A change in the use, management and practices around land and water (e.g., deforestation; fragmentation; modification of water regimes; forest degradation; land conversion for agriculture; ecosystem restoration; the role of women and men in land and water use and management, etc.)
Pollution and external inputs	The mismanaged, excessive or inappropriate use of external inputs (e.g., over application of fertilizer and pesticides; excessive use of antibiotics or hormones; nutrient loading, including from use of imported feed; ocean acidification, CO_2 fertilization; chemical and particulate pollutants, etc.
Over-exploitation and overharvesting	Unsustainable extraction practices (e.g., overfishing; overhunting; overgrazing; logging and extractive activities exceeding replacement rates or affecting species of uncertain and at-risk conservation status, etc.)
Climate change	The impacts and effects of progressive climate change (e.g., alterations in precipitation regimes; temperature changes; loss of water supply; increased variability; sea level rise; shifts in flowering time or seasonality, etc.)
Natural disasters	Climate shocks, extreme weather events and other natural disasters that threaten agricultural production and resilience of production systems (e.g., hurricanes, earthquakes, floods, fires).
Pests, diseases, alien invasive species	New and emerging threats from pests, diseases and invasive species affecting biodiversity for food and agriculture (e.g., shifting ranges; introductions; increased suitability; loss of predator, etc.)
Markets, trade and the private sector	**Trade-** Changing terms of trade, globalization of markets, commercialization of products, retailing, the separate capacities of women and women to commercialize products, etc. **Markets and consumption -** Demand driven changes in production or practices including the tastes, values or ethics of consumers that may impact directly or indirectly biodiversity for food and agriculture, product quantity or quality **Private sector -** The changing role and influence of private sector and corporate interests
Policies	**Policies** - Global, regional, national, and subnational legislation and regulations (e.g., conservation regulations, participation and compliance with International treaties and conventions); **Economic and policy interventions** - Interventions that impact biodiversity for food and agriculture directly or indirectly (e.g., taxes, subsidies, charges for resource use, payments for ecosystem services) **Intellectual Property Rights (IPR), Access and Benefit Sharing (ABS) -** Direct or indirect impacts of IPR and ABS policy and regulations on biodiversity for food and agriculture.
Population growth and urbanization	**Population** - Changes in population metrics (e.g., growth, fertility, composition, mortality, migration, health and disease, including different affects on men and women.) **Urbanization**- (e.g., shifts in proportion of urban and rural; change in urbanization trends, including different effects on men and women)
Changing economic, socio-political, and cultural factors	**Economic development** - A change in economic circumstances of countries, industries, households (e.g., change in GDP and economic growth; structural change of economy; income diversification, and the different economic circumstances of men and women.) **Changing socio-political, cultural or religious factors** - Variation in the forces influencing decision-making of men and women, e.g., public participation, shifts in the influence of the state vs. private sector, changes in levels of education and knowledge, shifts in the beliefs, values and norms held by a group of people.

	Participatory actions – the role of collective action toward conservation and use of biodiversity by stakeholders
Advancements and innovations in science and technology	The development and diffusion of scientific knowledge and technologies, (e.g., advances in breeding; improvements in mobile extension; tools for monitoring; biotechnology applications, access of men and women to information).

ANNEX 4: Ecosystem services

The SoWBFA Guidelines focus primarily on regulating and supporting ecosystem services, described below. Provisioning services relating to biodiversity for food and agriculture are the focus of sectoral State of the World Reports, and are addressed in these guidelines only in relation to associated biodiversity and wild foods, which often fall outside of traditional sectoral reporting. Countries may choose to address additional ecosystem services, including cultural services, for the completion of national reports, particularly where they are directly relevant to the objectives of the SoWBFA Report[37].

Table 1. Regulating and supporting ecosystem services.

Category	Ecosystem services	Description	Relevant ecosystem functions
Regulating services	Pollination	Role ecosystems play in transferring pollen from male to female flower parts	Agricultural productivity; production of food and goods.
	Pest and disease regulation	Influence ecosystems have on the prevalence of crop and livestock pests and diseases	Biological control; the maintenance and feedback mechanisms preventing outbreaks of pests and diseases, including invasive species.
	Water purification and waste treatment	Role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water; assimilation and detoxification of compounds through soil and subsoil processes	Filtering function performed by vegetation cover, soil and aquatic biota.
	Natural hazard regulation	Capacity for ecosystems to ameliorate and reduce the damage caused by natural disasters	Vegetative structure can alter potentially catastrophic effects of storms, floods and droughts through its storage capacity and surface resistance; coral reefs buffer waves and protect adjacent coastlines from storm damage. The services provided by this function relate to providing safety of human life and human constructions.
Supporting services	Nutrient cycling	Flow of nutrients (e.g., nitrogen, sulfur, phosphorus, carbon) through ecosystems	Maintenance of fertility; regulation of excess nutrients; climate regulation; regulation of biotic communities
	Soil formation and protection	Degradation of ecosystems, such as decomposition of organisms or weathering of substrate, to form soil	Maintenance of crop productivity on cultivated lands and the integrity and functioning of natural ecosystems.
	Water cycling	Flow of water through ecosystems in its solid, liquid, or gaseous forms	Regulation of hydrological flows at the earth surface. Maintenance of natural irrigation and drainage, buffering of extremes in discharge of rivers, regulation of channel flow, and

[37] Including those described in the Millennium Ecosystem Assessment, or subsequent adaptations by the TEEB or other sources.

			provision of a medium for transportation.
	Habitat provisioning	Role of ecosystems in creating and maintaining habitats for a wide variety of organisms	Providing diverse and suitable habitats for species; nursery function for migratory species and as breeding areas.
	Production of oxygen/ Gas regulation	The creation of atmospheric oxygen through photosynthesis	Gas regulation functions include the maintenance of clean, breathable air, and the prevention of diseases (e.g. skin cancer, asthma) May include regulation of the CO_2/O_2 balance, maintaining ozone-layer (O_3), and regulation of SOx levels.

ANNEX 5: Management practices supporting the use and conservation of biodiversity for food and agriculture

Table 1. Management practices supporting the use and conservation of biodiversity for food and agriculture.

Management practices supporting the use and conservation of biodiversity for food and agriculture	Description/ examples of management practices
Integrated Plant Nutrient Management (IPNM)	Soil, nutrient, water, crop, and vegetation management practices undertaken with the aim of improving and sustaining soil fertility and land productivity and reducing environmental degradation, often tailored to a particular cropping and farming system. May include the use of farmyard manures, natural and mineral fertilizers, soil amendments, crop residues and farm wastes, agroforestry and tillage practices, green manures, cover crops, legumes, intercropping, crop rotations, fallows, irrigation, drainage, plus a variety of other agronomic, vegetative and structural measures designed to conserve both water and soil.
Integrated Pest Management (IPM)	Pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment by encouraging natural pest control mechanisms that include: crop rotation; inter-cropping; seedbed sanitation, sowing dates and densities, under-sowing, conservation tillage, pruning and direct sowing; where appropriate, use of pest resistant/tolerant cultivars, push-pull strategies and standard/certified seed and planting material; balanced soil fertility and water management, making optimum use of organic matter; prevent spreading of harmful organisms by field sanitation and hygiene measures; protection and enhancement of important beneficial organisms.
Pollination management	Practices that accomplish or enhance pollination of a crop, to improve yield or quality, by understanding of the particular crop's pollination needs, and by knowledgeable management of pollenizers, pollinators, and pollination conditions. Pollinator-friendly practices include minimizing the use of agrochemicals, integrated pest management and mixed cropping to include pollinator friendly crops, preserving wild habitats, maintaining flower-rich field margins, buffer zones and permanent hedgerows to ensure habitat and forage, cultivating shade trees, managing for bee nest sites, and establishing landscape configurations that favor pollination services.
Landscape management	Practices that support the maintenance of biodiversity friendly farming systems, or the diversity of landscape mosaics within and surrounding production systems over particular geographic areas. Examples include riparian corridors, hedges, margins, woodland patches, clearings in forests, ponds or other biodiversity friendly features characteristic of the production environment that may be the result of national or regional policies such as the EU set aside schemes.
Sustainable soil management practices	Management of soil biodiversity to enhance agricultural production by both direct and indirect means, including alteration of the abundance or activity of specific groups of organisms through inoculation and/or direct manipulation of soil biota. Indirect interventions may include manipulation of the factors that control biotic activity (habitat structure, microclimate, nutrients and energy resources) rather than the organisms themselves such as the maintenance of soil cover with organic mulch

	including crop residues, green manure/cover crops including legumes, and compost to increase soil organic matter, irrigation and liming, as well as cropping system design and management.
Conservation agriculture	Conservation Agriculture (CA) aims to achieve sustainable and profitable agriculture and improve livelihoods of farmers through the application of the three CA principles: no or minimal soil disturbance through direct seeding into untilled soils, maintenance of permanent soil mulch cover, and crop diversification through rotations, associations and sequences.
Water management practices, water harvesting	Water harvesting and management through rain water retention or modification of the landscape (e.g., bunds, zais, terracing) for the restoration and improvement of degraded lands, and to allow cultivation of additional crops with higher water requirements, and improving water productivity of crops.
Agroforestry	Agroforestry is a collective name for land-use systems where woody perennials (trees, shrubs, palms, etc.) are integrated in the farming system.
Organic agriculture	Organic agriculture is a production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system.
Low external input agriculture	Production activity that uses synthetic fertilizers or pesticides below rates commonly recommended for intensive industrial tillage agriculture. It does not mean elimination of these materials. Yields are maintained through greater emphasis on agronomic practices, IPM, and utilization of on-farm resources (especially labor) and management.
Home gardens	An integrated system which comprises different components in a small area around the homestead, including staple crops, vegetables, fruits, medicinal plants, livestock and fish both for home consumption or use and for income. May include the family house, a living/playing area, a kitchen garden, a mixed garden, a fish pond, stores, an animal house, etc.
Areas designated by virtue of production features and approaches	These include areas recognized nationally or internationally by virtue of their landscape and agricultural features. In addition to Satoyama, GIAHS, national parks (IUCN categories), they also include areas recognized for specific agricultural products (e.g. DOP, IGP or Slow Food).
Ecosystem approach in capture fisheries	Approach promoting the diversity of the whole ecosystem in order to support the target species. Considerations include sustainable harvesting of the retained species (target and by-product species); managing the direct effects of fishing (especially on non-retained by-catch and habitat); and managing the indirect effects of the fishery on ecosystem structure and processes.
Conservation hatcheries	Hatcheries and production systems that optimize natural levels and organization of genetic diversity over production. Often for rebuilding depleted populations of commercially important species, (e.g. Atlantic and Pacific salmon).
Reduced-impact logging	A series of practices to improve logging practices such as vine removal, directional felling, limiting skid trails, logging roads and stumping grounds, restrictions on the size and number of trees felled, and post felling removal of waterway blockages, to reduce the residual damage, biodiversity loss and excess CO_2 emissions associated with conventional logging practices.

ANNEX 6: Diversity based interventions

Table 1. Diversity based practices and interventions

Diversity based practices	Description/ examples of interventions
Diversification	The introduction of new varieties, species, and groups of organisms (e.g., livestock, crops, trees, fish) into a production system or managed environment without replacement or abandonment of other groups, or the maintenance of already-existing diversity in the case of traditionally diverse production systems. May include introductions for restoration or IPM objectives, including fish introduced to control reproduction.
Base broadening	Increasing the amount of genetic diversity used to produce new varieties or breeds used in agricultural production.
Domestication	The development of new crop, aquatic, forest and animal species through deliberate breeding programmes or the continued selection and improvement of existing species from their wild progenitors. These activities may be carried out by national breeding programmes or by farmers and communities themselves.
Maintenance or conservation of landscape complexity	Maintenance or management of components of a landscape mosaic including hedges, waterways, road margins, corridors, windbreaks, living fences, native grasses wild patches of vegetation in the farming landscape, etc.
Restoration practices	Restoring functionality and productive capacity to ecosystems, forests, landscapes, waterways, grasslands and rangelands in order to provide food, fuel, and fiber, improve livelihoods, store carbon, improve adaptive capacity, conserve biodiversity, prevent erosion and improve water provisioning and quality.
Management of micro-organisms	The intentional incorporation, management or maintenance of microbes, fungi and other micro-organisms into a production system or organisms; e.g., inoculation of plants and seeds with arbuscular mycorrhizal fungi, the addition of probiotics in aquaculture and livestock, etc.
Polyculture/Aquaponics	Integrated multi-trophic aquaculture, utilization of different trophic and spatial niches of an aquaculture system in order to obtain maximum fish production per unit area, utilizing natural resource availability.
Swidden and shifting cultivation agriculture	Rotation of plots from intensive cultivation to extended fallow periods for the replenishment of soil fertility.
Enriched forests	Selective logging and enrichment planting to increase the abundance of useful species for food, medicine and timber, often a feature of traditional management practices.