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Water Conservation Practices in Agriculture to Cope with Water Scarcity

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Abstract: The increasingly demand for freshwater in last few decades, due to continued population growth and the direct impact of climate change, water supply limits and global warming, which leads to greater evaporation and thus surface drying, thereby increasing the intensity and duration of drought, especially in arid and semi-arid regions of the globe. In the coming decades, water experts are predicting more than half the world's population will suffer acute water scarcity by 2050. In order to avoid such a catastrophe, new habits and innovative technologies will be called upon to help the world's population to conserve and reuse existing sources of water. This concept is often described in terms such as sustainable water use, conservation, water-use efficiency, water productivity, reducing water footprint, breeding for high water-use efficiency crops, sustainable use of saline and groundwater, shifting from flood irrigation to sprinkler and drip irrigation systems, improved irrigation scheduling, using local climate and soil information to help farmers more precisely irrigate to meet crop water needs and applying less water to crops during drought-tolerant growth stages to save water and improve crop quality or yield and use of smart irrigation systems. Unconventional approach is planting non-traditional crops such as halophytic forage crops (*Leptochloa fusca, sporobolus virginicus, Kochia indica, Spartina patens, Kochia scoparia and Salicornia europeae*). These plants have an economic value and can tolerate harvesting ten times per year and were capable of recovering and maintaining a reasonable fresh productive biomass and its cellulosic biomass can use for ethanol production. Successive cuttings of these halophytic plants improve soil quality, decrease SAR and electrical conductivity (dS/m) since some of these plants can accumulate salts into their leaves vacuoles. Growing these plants as multi-use crops for forage and biofuel production on salt affected land that can be irrigated with brackish water or seawater. Thus freeing fresh water for food and feed, contribute to energy security, guarantee environmental sustainability. Other options are development of new varieties of crops adapted to heat, salinity and drought with short growing season to reduce their water requirements. Modify the techniques of irrigation, including water quantity, timing of irrigation, technology i.e. improve crop management under limited amount of available water to maximize the return by unit of water (water productivity) to fit growing in arid and semi-arid regions to produce more crops per drop in a world with water shortage.

Key words: Water conservation · Agriculture · Climate change

INTRODUCTION

Water scarcity has a huge impact on food production. Without water people do not have a means of watering their crops and, therefore, to provide food for the fast growing population. According to the International Water Management Institute Agriculture is both a cause and a victim of water scarcity, it accounts for about 70% of global water withdrawals, is constantly competing with domestic, industrial and environmental uses for a scarce water supply. In attempts to fix this ever growing problem, many have tried to form more effective methods of water management [1].

Demand for the world's increasingly scarce water supply is rising rapidly, challenging its availability for food production and putting global food security at risk. Agriculture, upon which a burgeoning population depends for food, is competing with industrial, household and environmental uses for this scarce water supply. Even as demand for water by all users grows, groundwater is being depleted, other water ecosystems are becoming polluted and degraded and developing new sources of

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water is getting more costly. Water development underpins food security, people's livelihoods, industrial growth and environmental sustainability throughout the world [2].

Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use. More than half the world's wetlands have disappeared. Agriculture consumes more water than any other source and wastes much of that through inefficiencies. Climate change is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others. At the current consumption rate, this situation will only get worse. By 2025, two-thirds of the world's population may face water shortages. And ecosystems around the world will suffer even more [3]. In this concern, Kang *et al*., [4] predicted that Africa will be one of the sectors most vulnerable to climate change and variability, because a significant proportion of the African economy is dependent on agriculture, most of Africa's water (85%) is used for agriculture, farming techniques are relatively primitive, the majority of the continent is already hot and dry, spatial and temporal changes in precipitation and temperature patterns will shift agro-ecological zones and thus have major impacts on the viability of both dry land and irrigated farming. Water scarcity is expected to become an ever-increasing problem in the future, for various reasons. First, the distribution of precipitation in space and time is very uneven, leading to tremendous temporal variability in water resources worldwide [5]. Second, the rate of evaporation varies a great deal, depending on temperature and relative humidity, which impacts the amount of water available to replenish groundwater supplies. The combination of shorter duration but more intense rainfall (meaning more runoff and less infiltration) combined with increased evapotranspiration (the sum of evaporation and plant transpiration from the earth's land surface to atmosphere) and increased irrigation is expected to lead to groundwater depletion [6].

Causes of Water Scarcity: The causes of water scarcity are varied. Some are natural and others are as a result of human activity. The current debate sites the causes as largely deterministic in that scarcity is a result of identifiable cause and effect. However, if water scarcity is the point at which water stress occurs (the point at which various conflicts arise, harvests fail and the like), then there are also less definable sociological and political causes. Many of the causes are inter-related and are not easily distinguished. Among the main causes of water scarcity are population growth, food production, climatic change and variability, water quality, water demand, poverty and economic policy, legislation and water resource management [7].

Changes in Precipitation Due To the Negative Impact of Climate Change: The availability of water is fundamental to agriculture. There is a direct influence of global warming on precipitation. Increased heating leads to greater evaporation and thus surface drying, thereby increasing the intensity and duration of drought. However, the water holding capacity of air increases by about 7% per 1°C warming, which leads to increased water vapor in the atmosphere [8]. He added that the observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as increasing atmospheric water vapor content, changing precipitation patterns, intensity and extremes, reduced snow cover and widespread melting of ice and changes in soil moisture and runoff. Precipitation changes show substantial spatial and inter-decadal variability, the impact of climate change can occur through three major routes: drought, which is a lack of water for a period of time causing severe physiological stress to plants, flooding which is an excess of water for a period of time causing physiological and direct physical stress to plants and timing of water availability [9]. There is much less certainty attached to rainfall projections under different climate change scenarios. However, an increased frequency in drought events is likely to be one of the most serious consequences of projected global warming [10]. A shortage of water affects plants by reducing the rate of photosynthesis, either through a direct effect of dehydration or through stomatal closure which reduces CO_2 intake [11]. An increased frequency and severity of drought events will mean that some areas which are currently marginal for the production of some rain fed crops will no longer be suitable for production. For example, in some areas of maize production in southern Africa there is already a high risk of significant yield loss or crop failure. An increase in the number of dry days or in the frequency of the early seasons of rains would make maize production unsustainable [12]. Where this is feasible, supplementary irrigation will be needed to counterbalance the higher soil moisture deficits. It has been estimated that globally, even taking into account greater water use efficiency resulting from higher levels of CO_2, there will be an increase of around 20% in net irrigation requirements by 2080 [13]. Fig 1 demonstrates projected water scarcity in 2025.

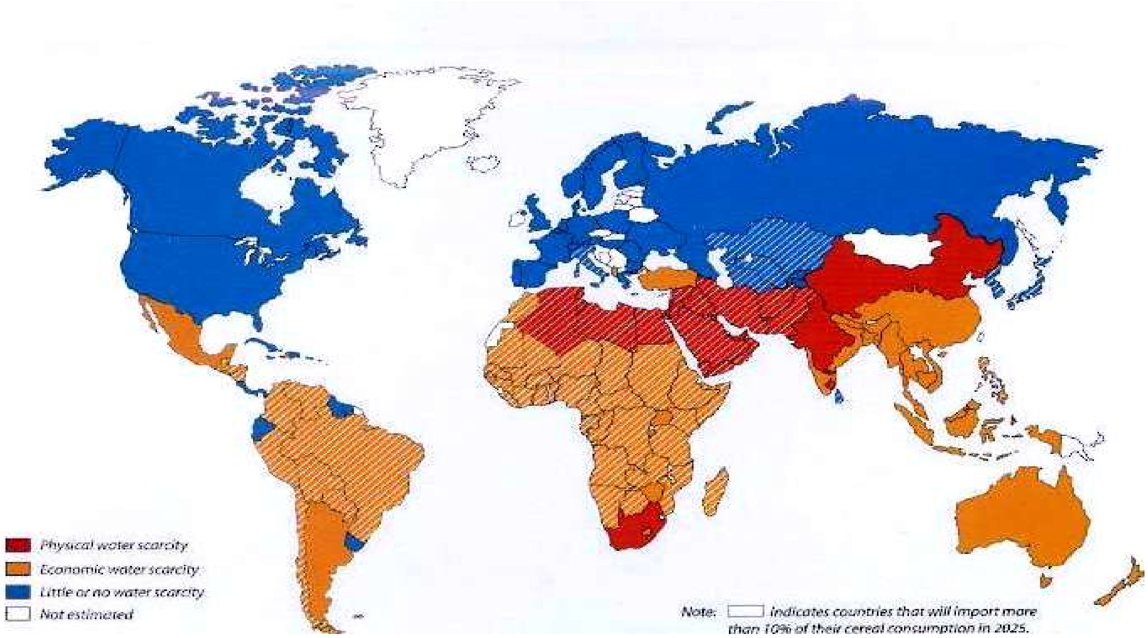

Fig. 1: Projected water scarcity in 2025.

Water Management to Cope with Water Sacristy

Sustainable Water Use and Management: The Intergovernmental Panel on Climate Change [10] predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe freshwater shortages or flooding resulting in negative impacts on agricultural production. Some studies suggest that by 2025, more than a third of the world population will face absolute water scarcity [14]. Enhancing water availability through adaptation technologies for sustainable water use and management is therefore a key strategy for increasing agricultural productivity and securing food security in these regions. Many options are available for improving the efficiency of water use for field crops agriculture. Among of these options, shifting from flood irrigation to sprinkler and drip systems, Improved Irrigation Scheduling, using local climate and soil information to help farmers more precisely irrigate to meet crop water needs and applying less water to crops during drought-tolerant growth stages to save water and improve crop quality or yield [15].

Using Sprinkler and Drip Irrigation Systems: Systems of pressurized irrigation, sprinkler or drip, can improve water efficiency and contribute substantially to improved food production. Sprinkler irrigation is a type of pressurized irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. These devices replenish the water consumed by crops or provide water required for softening the soil to make it workable for agricultural activities. The goal of irrigation is to supply each plant with just the right amount of water it needs. Sprinkler irrigation is method by which water is distributed from overhead by high-pressure sprinklers, sprays or guns mounted on risers or moving platforms. Table (1) shows the response of some field crops to sprinkler irrigation systems [16].

Table 1: Response of some field crops to sprinkler irrigation systems.

Crop	Water saving %	Yield increase %
Barley	56	16
Wheat	35	24
Maize	41	36
Groundnut	20	40
Cotton	36	49
Sorghum	32	42
Canola	25	32

Biotechnology for Water Stress Adaptation in Crops: The current challenges and future perspectives of biotechnology for decreasing the net profit of crops under the expected limited water conditions. The adoption of modern biotechnology through the use of genetically modified stress-tolerant, energy-efficient and high-yielding transgenic crops also stand to substantially counter the negative effects of climate change [17].

Fig. 2: Fog and dew harvest device.

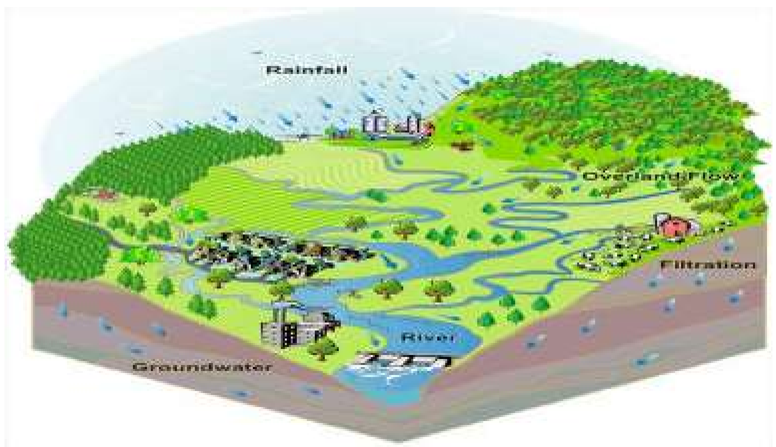

Fig. 3: Watershed

They added that, safe application of biotechnology will greatly complement other on-going measures being taken to improve agricultural productivity and food security. Both conventional and modern agricultural biotechnologies will significantly contribute to the current and future worldwide climate change adaptation and mitigation efforts [18]. Biotechnology and application of advanced techniques in breeding can help agriculture further to achieve higher yields and meet needs of expanding population with limited land and water resources [19].

Fog and Dew Harvesting: Fogs have the potential to provide an alternative source of fresh water in dry regions and can be harvested through the use of simple and low-cost collection systems. Captured water can then be used for agricultural irrigation and domestic use. Fog or dew collection is an ancient practice [20]. Archaeologists have found evidence in Palestine of low circular walls that were built around plants and vines to collect moisture from condensation. In South America's Atacama Desert and in Egypt, piles of stones were arranged so that condensation could trickle down the inside walls where it was collected and then stored [21]. Research suggests that fog collectors work best in locations with frequent fog periods, such as coastal areas where water can be harvested as fog moves inland driven by the wind by using the data (hourly dry and wet temperature, relative humidity, wind direction and velocity and the dew point temperature), various parameters such as the atmosphere water vapor pressure, saturated vapor pressure and the absolute humidity of the atmosphere can be estimated. However, the technology could also potentially supply water in mountainous areas if the water is present in stratocumulus clouds [22], who prove in an investigations carried out in two regions in Iran, it was clear that the cited regions had the potential to harvest fog and moisture from the humid atmosphere for 160 - 360 days. The annual mean water harvested through this technique varies between 6.7 lit / m^2 / day at Abadan station to 156.3 lit / m^2 / day at Chabahar station (Fig. 2).

Watershed Management: A watershed is a basin-like landform (Fig. 3). A watershed is simply the geographic area through which water flows across the land and drains into a common body of water, whether a stream, river, lake, or ocean. Much of the water comes from rainfall and the storm water runoff. The quality and quantity of storm water is affected by all the alterations to the land-agriculture, roadways, urban development and the activities of people within a watershed. Watersheds are usually separated from other watersheds by naturally elevated areas. A watershed carries water "shed" from the land after rain falls and snow melts, drop by drop, water is channeled into soils, ground waters, creeks and streams, making its way to larger rivers. Watershed management (IWM) is the process of managing human activities and natural resources on a watershed basis. This approach allows us to protect important water resources, while at the same time addressing critical issues such as the current and future impacts of rapid growth and climate change [23].

Breeding for High Water-Use Efficiency Crops: There is a pressing need to improve the water-use efficiency of rain-fed and irrigated crop production. Breeding crop varieties with higher water-use efficiency is seen as providing part of the solution. Three key processes can be exploited in breeding for high water-use efficiency: (i) moving more of the available water through the crop rather than it being wasted as evaporation from the soil surface or drainage beyond the root zone or being left behind in the root zone at harvest; (ii) acquiring more carbon (biomass) in exchange for the water transpired by the crop, i.e. improving crop transpiration efficiency; (iii) partitioning more of the achieved biomass into the harvested product [24].

Sustainable Use of Saline Water for Irrigation: Worldwide, there is insufficient fresh water to develop all potential arable land. So, the use of saline water in agriculture is a subject of vital importance especially for arid and semi-arid zones to meet the increasing food demand [25]. Growing agricultural crops with direct seawater irrigation has progressed within the past few years from the conceptual to the experimental phase. This has been accomplished by selecting halophytes within inherently high salinity tolerance for use as crop plants rather than by increasing the ability of traditional crop plants to tolerate seawater. Three approaches are being used by researchers in various parts of the world to develop salt tolerant crops. In the first approach, searches have been initiated with traditional crops for salt tolerant cultivars, second approach that has been proved successfully, is the crossing of commercial species low in salt tolerance with wild salt tolerance relatives and the third approach has been to begin with wild species that have evolved high salt tolerance in their native habitats [25]. The fact remains that no conventional agricultural crops are yet grown with undiluted seawater, even on sand dunes [26]. The seawater can be used to supplement agricultural water supplies, but only under very special conditions. Seawater irrigation would be feasible in coarse textured soils at different dilution levels, depending on the variations extent in salt tolerance of plants [25].

Sustainable Use of Groundwater: The sustainability of intensive groundwater development for irrigated agriculture from the very extensive quaternary aquifer system constitutes one of the world's major water resource management issues. Unlike other natural resources or raw materials, ground water is present throughout the world. Possibilities for its abstraction vary greatly from place to place, owing to rainfall conditions and the distribution of aquifers (rocks, sand layers and so on, in whose pore spaces the groundwater sits). Generally, groundwater is renewed only during a part of each year, but can be abstracted year-round. Provided that there is adequate replenishment [27]. Groundwater constitutes the underground part of the water cycle (Fig. 4). Therefore, it is closely related to atmospheric or climatic processes, to the surface water regimes of rivers and lakes and with the springs and wetlands where groundwater naturally discharges onto the surface of the ground. All these resources are complementary, but they can be extremely varied - extending from arid areas with virtually no water to humid tropical zones with abundant surface water and rainfall [28].

Eco-Friendly System for Desalination of Seawater: The world's water consumption rate is doubling every 20 years, outpacing by two times the rate of population growth. It is projected that by the year 2025 water demand will exceed supply by 56%. The distilling of sea water is an old dream because salt-free water is in danger of running out. The seas have endless quantities of water. Water becomes salt-free by distilling it, but it requires a lot of energy. With the help of the renewable source of clean energy (e.g. solar energy). Desalination has become possible recently, but still desalination is expensive, at least in the sense that it requires large investments [29].

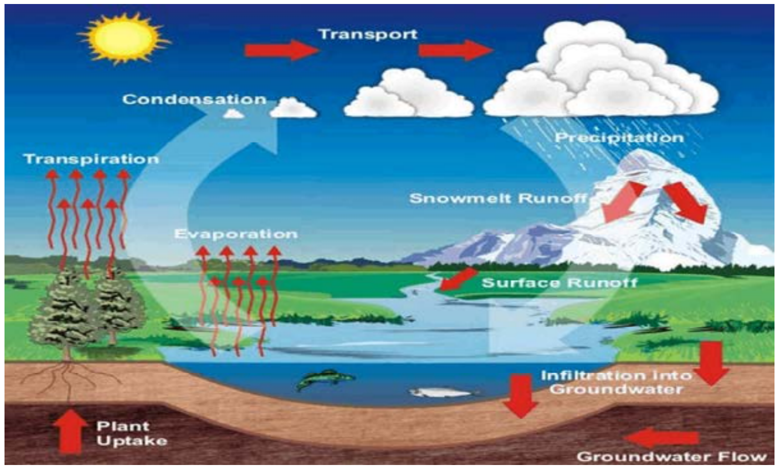

Fig. 4: Water cycle.

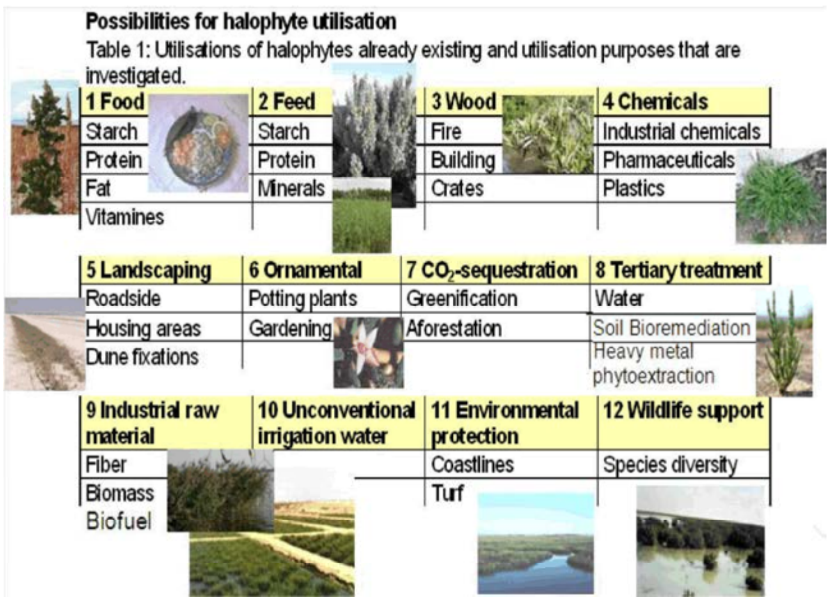
Possibilities for halophyte utilisation

Table 1: Utilisations of halophytes already existing and utilisation purposes that are investigated.

1 Food	2 Feed	3 Wood	4 Chemicals
Starch	Starch	Fire	Industrial chemicals
Protein	Protein	Building	Phamaceuticals
Fat	Minerals	Crates	Plastics
Vitamines			

5 Landscaping	6 Ornamental	7 CO_2-sequestration	8 Tertiary treatment
Roadside	Potting plants	Greenification	Water
Housing areas	Gardening	Aforestation	Soil Bioremediation
Dune fixations			Heavy metal phytoextraction

9 Industrial raw material	10 Unconventional irrigation water	11 Environmental protection	12 Wildlife support
Fiber		Coastlines	Species diversity
Biomass		Turf	
Biofuel			

Fig. 5: Some possibilities for halophytes utilization.

Water Pricing Policy: The new water pricing strategy, addresses the challenges presented by the existing and growing imbalances between the availability, supply and demand for water in the world. The policy introduces demand-side measures to manage our water resources, by encouraging all water sectors to use water more efficiently, provides a more sustainable long-term solution to the problem of water scarcity, because it takes into account the value of water in relation to its cost of provision, thereby treating it more like a commodity [30].

Halophytic Plants

A Nonconvential Smart Crop for the Future: Water scarcity due to climate change has been increasing and the problem is more severe in arid and semi-arid regions and cause poverty and other related social and economic issues [31]. Moreover, 43% of earth land mass is arid or semi arid and 97.5% of its water is saline [32], over 800 million hectare of the world is affected by salinity [33], 45 million out of 230 million hectare of prime irrigated agricultural land has become saline and the menace is creeping into arable lands [34]. Cultivation of halophytes on these vast degraded saline lands by using huge resource of under-ground brackish water or even seawater in some cases would spare arable land and fresh water for conventional agriculture. An integrated approach therefore is imperative for the sustained development. Utilization of saline resources to mass produces halophytes of economic importance e.g. as vegetable, forage and oilseed crops in agronomic field trials Fig 5.

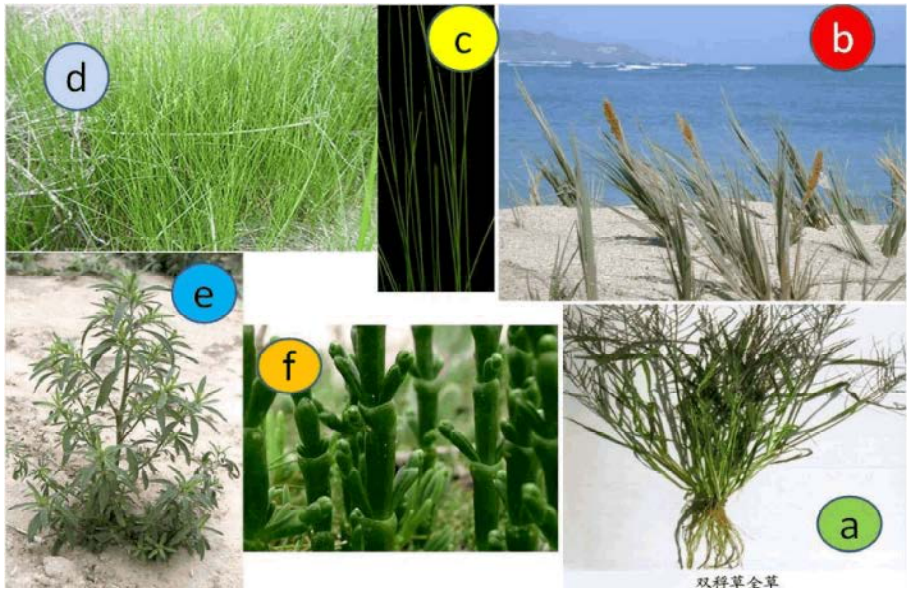

Fig. 6: Some halophytic plants species a: Leptochloa, b: Sporobolus, c: Juncus, d: Spatina, e: Kochia, f; Salicornia.

Moreover, they have been used for bio-remediation of salt contaminated soils and even pharmaceutical values of their products could be one such strategy to address water issue [35]. Figure 6 shows some representative halophytic plants

Smart Biofuel Crops: Biofuel as bio-ethanol and bio diesel have the potential to assume an important portfolio in future energy platter. Food security concerns and risks to environment and biodiversity are parameters that necessarily need to be accessed while analyzing sustainability linkage of agriculture and biofuel. Also, conversion of wasteland to farmland with some crop options can be viewed as positive impacts. Recently we use the term (Smart Bioenergy Crops), SBC are crops that ensure food security, contribute to energy security, provide environmental sustainability, tolerate the impacts of climate change on shortage of water and high temperatures and increase livelihood options [36]. By producing non-food ligno-cellulosic biomass which, may be converted into ethanol without compromising human food production. Halophytes which produce plenty of biomass using saline resources (water and soil) may be an important alternative. *Leptochloa fusca*, *Kochia scoparia*, *sporobolus virginicus* and *Panicum turgidum* have potential as bio-ethanol crops. These perennial grasses are halophytic plants with high growth rates to produce ligno-cellulosic biomass of good quality (37% cellulose, 38% hemi-cellulose) for ethanol production [33]. Another approach is using the vast desert in the world and grows some drought and heat tolerant plants (e.g) *Jatropha curcas* to get biodiesel, reduce GHG emission, energy security, maintain soil fertility and reduce soil erosion [37].

Increasing Water Productivity and Water Footprint: Increasing water productivity holds the key to future water scarcity challenges. Without further improvements in water productivity or major shifts in production patterns, the amount of water used for agriculture, industrial and domestic activities will increase by 60–90 percent by 2050, depending on population, incomes and assumptions about water requirements for the environment. In agriculture alone, the total volume of water used in crop production would be 11 000–13 500 km^3, almost double the 7 130 km^3 of today. However, there is scope for an accelerated increase in water productivity. Water productivity in agriculture has increased steadily in recent decades, largely owing to increasing crop yields and the potential exists for further increase. However, the pace of such increase will vary according to the type of policies and investments put in place, with substantial variations in the impact on the environment and livelihoods of rural populations. Targeted investments in all sectors, combined with a package of institutional measures that promote enhanced efficiency while guaranteeing equity in access to water, can do much to alleviate water scarcity and secure environmental sustainability [38].

Wastewater Reuse: Looking at the water circle, one can assert that there is no production of new water. This guides to the conclusion that all water on earth is reused water. Reuse of water is an effective contribution to the management of limited water resources in the fields of agriculture, housing and settlement, industry and other purposes. Proper reuse of water can be accomplished through treatment techniques and appropriate use of reclaimed water. Reclaimed Water, also known as recycled water, is water recovered from domestic, municipal and industrial wastewater treatment plants that has been treated to standards that allow safe reuse [39]. Properly reclaimed water is typically safe for most uses except human consumption. It can be used in agriculture, by mixing it with fresh water, thereby economizing the use of the latter, or used to grow non-food crops in currently un- or under-utilized desert areas, where it would otherwise serve no useful purpose. Put differently, it enables horizontal expansion with little or no opportunity cost, at least with respect to two key inputs – land and water. Moreover, it can be used to recharge groundwater, thereby supplementing fresh water supplies for irrigation and other purposes, while at the same time storing water without evaporation losses or the risks associated with dams [40].

The Situation in Egypt: Egypt is located in the north-eastern corner of the African continent with an area about one million square kilometers. It is considered a developing country burdened by the scarcity of natural resources associated with extreme population growth (over 85 million people in total). The inhabited area of the country constitutes only 5% of the total area of the country which is confined to the narrow strip of the Nile valley and Delta. Its only source of water -the River Nile- provides more than 95% of all water available to the country. The source of this water comes from rainfall on Ethiopian hills (86%) and equatorial lakes (14%) [41]. Egypt considered one of the top five countries expected to be mostly impacted with climate changes [42]. Moreover, climate change will probably affect water resources requiring reduction in irrigation water and that might pose another problem for agricultural production [41]. Climate change poses significant risks through sea level rise on the coastal zone, which is already subsiding at approximately 3-5mm/year, with country averaged mean temperature increases of 1.4°C and 2.5°C projected by 2050 and 2100 [43]. Sea level rise will adversely impact prime agricultural land in the Nile delta through inundation and salinization. Egypt's climate is expected to get drier and warmer thus pressures on agriculture will affect field crops productivity and also their water use efficiency [44].

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