Biosaline agriculture as an approach for combating desertification

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3 AUTHORS:

Abdullah Dakheel
International Centre for Biosaline Agriculture

Kameswara Rao Nanduri
International Centre for Biosaline Agriculture

Richard Soppe
International Centre for Biosaline Agriculture

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Dr Abdullah Dakheel, Dr Rao Nanduri and Dr Richard Soppe, International Center for Biosaline Agriculture, Dubai

Desertification has several causes, including population pressure, changing climatic conditions, economic, political and social conditions, and lack of access to science and technology.

The Millennium Ecosystem Assessment lists overgrazing as one aspect of the desertification cycle, when land and water do not provide enough resources for sustainable grazing. Salinization of soils is another chain in the process towards desertification. Desertification usually results in more poverty which in turn strengthens the conditions leading to desertification. Rehabilitation of desert systems requires the adoption of multiple strategies including the rehabilitation of natural degraded ecosystems and the use of the limited water resources in agriculture production, afforestation and aquaculture systems in certain cases. However, water resources in deserts are in most cases limited to groundwater of ancient origin or shallow aquifers that mostly have became salinized due to overutilization and depletion. In coastal and subcoastal deserts seawater and highly salinized groundwater resources exist in large quantities; however their use in rehabilitation requires the use of special agroecosystems that can tolerate such high levels of salinity.

An approach to break this cycle is through the application of biosaline agriculture at different locations in the landscape. More salt-tolerant and drought-tolerant plants can be introduced, allowing the use of marginal water resources to increase plant production for foraging or fodder, thus reducing the risk of overgrazing. Higher-value salt-tolerant plants and trees can be introduced to provide a source of income to local populations. In addition to introducing landscape management, socioeconomic and (implementation of) policy decisions are needed. The introduction of managed forage land under saline conditions, for example, should not result in an increase of the grazing population larger than the carrying capacity of the managed lands.

Several aspects need to be considered when biosaline agriculture is introduced. Introducing new genetic resources (new genotypes or more salt-tolerant species) requires access to seeds, or introducing nurseries, as well as an assessment of crop diversity and management to maintain the local diversity (prevent invasive species to compete out the local genotypes and varieties, for example as is the case with wild melon in Australia). Maintaining the local biodiversity ensures an ecosystem that is adaptable to changing environmental conditions.

Image: ICBA

Rehabilitation of desert areas with salt-tolerant grasses (Oman)

Salicornia is produced on a large scale and irrigated with seawater in coastal areas

The economics of the introduced biosaline agricultural system are important. Since desertification is related to the poverty cycle and marginal agricultural ecosystems, it is important that the new landscape management system has a positive contribution to the local economy. Two examples are the introduction of more salt-tolerant date palms, a cash crop with an already existing market system in many desert-prone areas, and quinoa, a high market value crop which produces seeds and biomass well under marginal conditions (salinity, high temperatures and drought).

Providing forage and grazing genotypes and varieties that are adapted to marginal conditions (such as drought and salinity) also requires an analysis of the nutritional value, and the palatability of the introduced crops. A crop can be growing well under the marginal conditions, but if it does not have a nutritional addition, or if the small ruminants are not willing to consume it as part of their diet, the value of the crop is limited for the region.

In some areas, only seawater is available. Some plants growing under hot, coastal conditions, halophytic plants, can provide an economic value, for example plants from the Salicornia genotype. In the Netherlands, a market chain was developed and supported, including the development of customer demand through the introduction of cooking classes and recipes, for Salicornia imported from the coastal and desert areas in Mexico.

Land and water management needs special attention when managing agroecosystems under dry and saline conditions. Water resources are often non-renewable (fossil groundwater) and application of saline water on soils without considering the potential accumulation of salts can lead to non-sustainable, short-term solutions. Although in some cases, short-term solutions can be applied to overcome crises periods, the long-term aim of land and water management in fragile and marginal environments is to develop sustainable solutions.

When saline water is used for crops, forestry or any type of biomass growth, evaporation and transpiration will result in an increase of concentration of salts. These salts, previously stored in the water source (groundwater, seawater or other surface water sources) are increasing in concentration due to evapotranspiration, but also due to the spatial accumulation at the locations where plants are grown and irrigated. Consideration of where the accumulated salts are stored is a necessity under biosaline agriculture. Options are to store salts in the soil below the active root zone (through leaching of salts, that is the application of excess water to move the accumulated salts away from the plant roots), leach salts into the groundwater (less preferable), or concentrate salts in evaporation ponds where they can be collected in solid form and taken out of the agro-production system).

Six different groups of biosaline systems have been piloted in the Arabian Peninsula, providing opportunities to break the poverty cycle, green the desert and reclaim salinized lands. These groups can be classified as conventional forage production systems; non-conventional forage production for subcoastal and coastal deserts; high-value crops and date palms; medicinal crops production systems; seawater-based systems including aquaculture; and production systems based on treated wastewater.

Forage production systems

Water scarcity and salinity are two of the biggest constraints to agricultural production in several counties in the Middle East and North Africa region. In the United Arab Emirates (UAE), over the years, more than 70 per cent of the farms were dedicated to forage production, mainly with Rhodes grass (*Chloris gayana*) — a high water consuming crop. The large-scale cultivation of this fodder grass species to meet the increased demand for forages in the emirate, has had a profound impact on the usage of water resources for agriculture and contributed to the depletion of the groundwater reserves faster than the aquifer recharge that depends on the scanty rainfall and as well as in increased aquifer salinization due to intrusion of seawater, especially in the coastal areas with close to 4,800 farms facing the risk of abandonment. In a pilot project on three farms in the UAE, four halophytic perennial grass species were planted: *Distichlis spicata*, *Sporobolus virginicus*, *S. arabicus* and *Paspalum vaginatum*. The new grasses, with the mean green biomass yields ranging between 122 t/ha and 141 t/ha per year and dry matter yields between 24 t/ha and 42 t/ha per year, proved to be excellent and viable alternatives to Rhodes grass for sustainable forage production in salt-affected/degraded farms. In terms of water productivity, the forage yields obtained per cubic metre of highly saline water (15-18 dS/m) were 66 per cent more than the yields reported for Rhodes grass with low salinity water (2 dS/m). In terms of water saving, it means saving 44 per cent of water to produce the same amount of forage as Rhodes grass.

Potential high-value crops

Several neglected and underutilized species, because of their resilience and natural adaptation to harsh growing conditions, can provide alternatives to the staple crops to sustain farm productivity in desert environments constrained by water scarcity, poor soil fertility and other such yield-limiting factors. Among the species native to or naturalized in the Middle East, Christ's thorn jujube (*Ziziphus spina-christi*), purslane

Salt-tolerant and drought-tolerant plants allow the use of marginal water resources to increase plant production and reduce overgrazing

(*Portulaca oleracea*), jute mallow (*Corchorus olitorius*), rocket (*Eruca sativa* and *Diplotaxis tenuifolia*), safflower (*Carthamus tinctorius*) and wild drumstick tree (*Moringa peregrina*) have considerable value in terms of their tolerance to salinity and harsh climatic conditions. Many such species have the potential for more widespread use and their promotion could contribute to food security, agricultural diversification and income generation, particularly in areas where cultivation of major crops is constrained or economically unviable. Similarly, salt- and drought-tolerant non-native species such as leaf mustard (*Brassica juncea*), quinoa (*Chenopodium quinoa*), salicornia (*Salicornia bigelovii*), guar (*Cyamposis tetragonoloba*) and amaranth (*Amaranthus cruentus*) which showed good adaptation in field trials under harsh conditions in the UAE, are likely to be of value in providing cost-effective and long-term solutions to problems of water shortage and increasing salinity of soil and water resources in the region. Besides their tolerance to abiotic stresses, all these species are nutritionally rich and can thus play a crucial role in combating vitamin and micronutrient deficiencies frequently experienced by inhabitants of marginal environments. Research to improve the productivity and value of these crops, and to encourage them to be more widely cultivated, would contribute to food, income and nutritional security for smallholder farmers in marginal environments.

Medicinal crop production systems

In combating desertification, integration of biodiversity conservation into economic development — accomplished through sustainable production and commercialization of natural products derived from native plants — is beginning to emerge as a major strategy in several countries. Deserts harbour a variety of flora adapted to the dry conditions and surviving for several years without water. The medicinal value of these plants is well known, for example, nearly 20 per cent of the 750 native plant species documented in the UAE are known to have medicinal properties. Two good example are *Aloe vera* (sabar), a shrubby xerophytic, succulent plant used for centuries for its health, beauty, medicinal and skincare properties, and *Cynomorium coccineum* (tarthuth) a parasitic plant considered as a 'treasure of drugs' because of its numerous traditional therapeutic uses in treating colic and stomach ulcers, piles, nosebleeds, dysfunctional uterine bleeding and as a contraceptive. Most medicinal plants are still being collected from the wild population and many are being seriously threatened by overgrazing and habitat degradation. According to the UAE Red Data plant list, of the 132 species of medicinal plants, six species fell under the threatened category. Thus, it is important to integrate commercial exploitation with action plans for sustainable conservation and use.

Seawater and brine-based systems

To provide additional income and reduce the poverty cycle, improving water supply for human consumption and irrigation purposes requires the desalination of groundwater. Approximately 15 per cent of farmers in the Arabian Peninsula have installed small-scale reverse osmosis (RO) plants to desalinate the groundwater for field crop irrigation. These RO plants produce highly concentrated brine which can be used as a resource under best management practices. A project to showcase the potential of a farming system using seawater-level brine was developed in the UAE. The desalinated water is used to irrigate a large variety of high-value vegetable crops (such as asparagus, eggplant and radish). The produced brine is used for aquaculture, followed by irrigation of salt-tolerant forages and halophytic plants. The mariculture system contains fish, sedimentation and seaweed tanks. Two fish species (sobaity seabream and tilapia) showed adaptability to the fish tank conditions in the Emirati climate. One of the halophytic species irrigated with brine is *Salicornia bigelovii*, a multipurpose species that can be used as a vegetable, biofuel or fodder. Previous research found that cultivating the proper salicornia varieties, combined with suitable agronomic practices, could be economically viable and successful in marginal land.

Production systems based on treated wastewater

Arab countries are expected to face severe water scarcity as early as 2015, when the annual per capita water share in the region will fall to less than 500 m^3. Give that agriculture uses 70-80 per cent of all water, the reuse of reclaimed (treated) wastewater for irrigation could contribute considerably to the reduction of water scarcity for domestic use. In many countries of the Arabian Peninsula, due to the problem of social acceptance and the perception of health risks, municipal wastewater, even after tertiary-level treatment, is not used for growing food and feed crops. In the UAE, of the 600 MCM of tertiary-treated wastewater produced per year, 58 per cent (352 MCM) is used mainly for landscaping and the rest is discharged into the sea. In fact, reclaimed wastewater can be a valuable resource to grow bioenergy crops for the specific purpose of producing liquid fuels, with considerable economic and environmental benefits, when social barriers prevent its use for growing edible crops. If bioenergy crops can be cultivated on a commercial scale, they can reduce pressure on fossil fuels while simultaneously improving environmental quality and reducing desertification/soil erosion which is also a matter of serious concern in the region.