Functional rehabilitation of desertified ecosystems in Israel: ecological and socioecological perspectives

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The multifunctional cultural landscape in the southern arid and semi-arid region in Israel (the Northern Negev), has been shaped by human activity over the millennia. These anthropogenic ecosystems, common to the Northern Negev, are degraded systems that regularly lose soil and water resources necessary to support the ecosystem in its entirety.

Desertification processes in Israel are caused by uncontrolled land-use such as grazing, vegetation removal, cultivation and the neglect of ancient agricultural sites. The results include decreased landscape diversity and primary productivity, increased flood intensity and soil erosion, degradation of water resources, and harm to native flora and fauna.

Keren Kayemeth LeIsrael — Jewish National Fund (KKL-JNF), a national organization responsible for afforestation and land reclamation in Israel, has accumulated rich experience and advanced knowledge through years of research and day-to-day field management, and can offer a unique set of tools for confronting these desertification processes.

KKL-JNF rehabilitates desertified areas in Israel based on long-term research that combines, measures and quantifies ecosystem processes and feedbacks which have changed due to desertification. This knowledge base enables KKL-JNF to

Image: David Brand

A typical view of degraded areas in the arid zone of Northern Negev

Image: Itshack Moshe

Water harvesting plays a major role in sustainable afforestation in Northern Negev's arid zone

develop theoretical and practical frameworks for restoring ecosystem functions in highly depredated areas in order to improve ecosystem services.

This framework views desertification and rehabilitation as part of a complex socioecological system in which human activities shape the cultural landscape and create desertified and rehabilitated novel ecosystems. The framework includes an ecological perspective that identifies the drivers of desertification and rehabilitation processes in the Northern Negev and a sociological-landscape perspective that integrates desertification and rehabilitation concepts with cultural landscape and ecosystem services concepts.

Desertification processes, in the past and present, are caused by human activities and overexploitation of natural resources in conjunction with climatic extreme events such as prolonged drought. The results of these processes are desertified ecosystems, seen in Israel in the Northern Negev region, characterized by a high level of system degradation as determined by indicators for soil erosion, water loss and primary productivity.

Research in earth and ecological sciences discovered the key processes that shift water-limited ecosystems from the state of desertification to rehabilitation. In a healthy and functional state, the main mechanism by which water-limited ecosystems conserve and use water, soil and biological resources is through redistribution of rainfall via changes to surface run-off absorbed in woody plants patches. The woody plant patches, which capture and retain surface run-off, function as localized 'resource sinks' and create resource-enriched patches. These patches, enriched with water and soil resources, exhibit relatively high biological productivity and diversity.

Desertification drivers, such as grazing and drought, cause a significant reduction in run-off 'sinks' made of woody vegetation, resulting in reduced water conservation and increased water leakage. As a consequence of changes in the water flow and its spatial distribution, soil erosion increases and biological productivity and diversity decreases. This trajectory in ecosystem dynamics — the transition from conservation to loss of resources — leads to a state of ecosystem degradation.

The degradation state affects landscape functions which provide ecosystem services in the Northern Negev by creating a novel set of ecosystems in which the dominant component is a biotic soil crust that replaced the woody plants. This component prevents water conservation in the form of soil moisture and leads to increased water loss as surface run-off. The novels ecosystems differ in form and function from the woody dominated ecosystems that existed prior to human habitation in the Northern Negev. The current degraded ecosystems were formed over thousands of years, and were affected by the physical and biological changes that resulted from diverse and wide-ranging human activities. These novel desertified ecosystems function, but human history has shaped them to a low functional level as expressed by their reduced ability to store system resources and transport them to the biotic elements for ecosystem production. Presently, desertified ecosystems in the Northern Negev are characterized by a high

Image: 'Albatross' – KKL Archive

Hiran forest after rehabilitation activities

level of system degradation as determined by indicators for soil erosion, water loss and primary productivity.

Ecological models describing the functional attribute of ecosystems in the Northern Negev reveal that an increased rate of system degradation can be expected due to the following trends: increased urban development and its associated demographic pressures (increased built-up areas); high-intensity cultivation of agricultural lands; lack of maintenance of ancient agriculture sites, and increased grazing pressure. In addition, predicted trends in global climate change may result in more extreme weather events (incidences of unusual droughts and storms), thus exacerbating degradation processes.

Identification of the pathways and trajectories of desertification processes enables formulation of the pathways and trajectories for functional rehabilitation of the ecosystems, where functional rehabilitation implies restoring the ecological functions of the system prior to desertification. This necessitates reversing the system functioning from a system that loses water and soil to one that conserve these resources. When the system conserves resources its cascading functional responses are an increase in biological productivity and diversity.

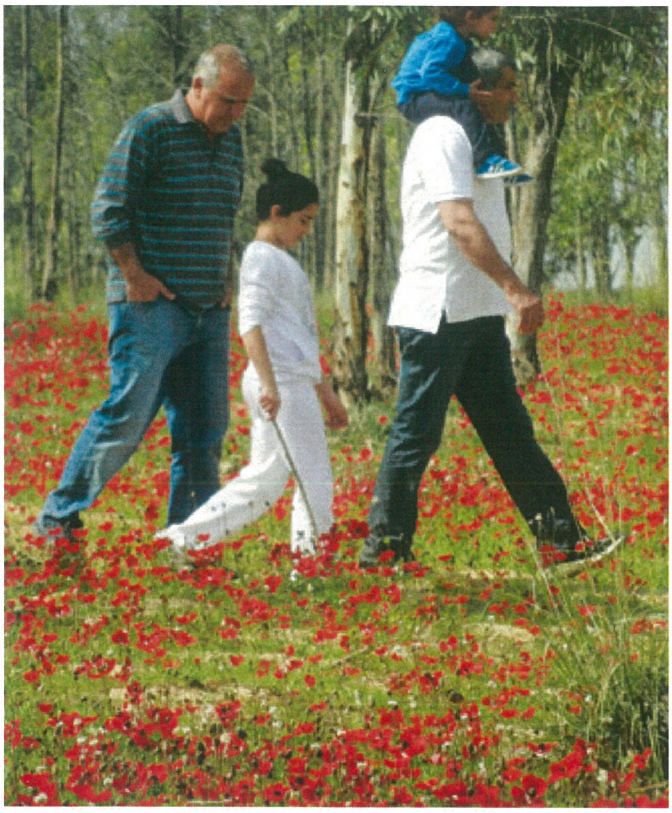
KKL-JNF acts to functionally rehabilitate the desertified ecosystems in the Northern Negev by landscape modulation through the construction of a mosaic of 'mini run-off catchments' for harvesting the surface run-off generated by the soil crust. This rehabilitation framework restores the pre-desertification functions of rainfall water redistribution and creates a landscape of soil moisture enriched patches that conserve resources and enhance biological productivity. In reshaping landscape structure, the human-made rehabilitated ecosystems regain the ability to preserve their scarce resources while renewing their ability to supply ecosystem services for human welfare.

System rehabilitation and the reversing of degradation processes by management intervention by KKL-JNF is based on a scientific understanding of the connections between hydrological processes and ecosystem structure and function in water-limited zones. This includes understanding the rainfall/run-off/soil moisture relationship on the slope and watershed scales, as well as the connection of water flow to ecological processes such as productivity and diversity on the landscape level.

Viewing rehabilitation as a management intervention to regulate ecosystem functions is the road map that directs KKL-JNF management actions and is translated into specific activities, such as:

- alteration of the ecosystem's physical infrastructure — constructing various measures for run-off harvesting on slopes and valleys as well as measures to stabilize erosion processes such as gully heads; facilitating in-situ storage of scarce water and soil resources, and encouraging the regeneration of biotic components on site
- afforestation — tree plantation to supply ecosystem services for human welfare.

The functional rehabilitation of an ecosystem restores the integrity of fundamental hydrologic, edaphic and ecologic processes, which are directed towards creating a novel,



Images: Itshack Moshe

Bicycle trails, native flowering sites, parks and community forests are just some of the cultural services which improve the life quality of inhabitants

highly functional and sustainable ecosystem. The integrity of the ecosystem is restored because the following key processes are regulated by management:

- redistribution of on-site rainfall through changes to surface run-off harvesting patterns
- enhancement of natural soil patches and the creation of artificial ones which capture and retain surface run-off, thus functioning as localized resource sinks.

These patches, enriched with water and soil resources, exhibit increases in primary productivity.

In sum, the aforementioned approach towards system rehabilitation to restore landscape heterogeneity involves the creation of artificial sinks on slopes and valleys, which collect and store run-off rainwater, thus producing patches enriched with water and nutrients. The infiltration of captured surface run-off into the soil creates water-rich microhabitats and improved soil quality, enabling the possibility to plant trees to create a novel ecosystem. The human-made novel ecosystem reinforces the system's ability to supply benefits to humans and other organisms living there. The choice of which tree species to plant and the configuration of the planting are adapted to landscape and soil moisture spatial heterogeneity, soil, site-specific topographic, and edaphic factors. The use of a diverse set of tree species guarantees resilience and durability of the novel ecosystems to the stresses of drought, grazing and human activity.

The historic long-lasting, widespread and large-scale human land use in the Northern Negev has result in a land surface which can be considered a mosaic of cultural landscapes, in which different stages of anthropogenic influences have been overlaid and refined, resulting in alternating periods in which desertification and of rehabilitation prevail. Therefore, the mosaic of ecosystems that form the cultural landscapes can be understood as the result of the dynamics of social-ecological systems, in which social, economic and environmental components are closely interwoven.

Cultural landscapes imply landscapes that are deliberately managed by humans and that their ecosystem services have been sustained through a long and complex history of human settlement, land use and misuse.

KKL-JNF adopted a cultural landscape framework that provides a new perspective on desertification and rehabilitation as interactions between man and nature, by understanding of the role of humans in landscapes and ecosystems transformation in the Northern Negev. In this view, landscape management means integrating natural processes and human engineering in a functional way, as described in the previous section, in order to provide ecosystem services. Functional rehabilitation is therefore a comprehensive framework that connects the cultural landscape with its ecosystem services.

Through its years of varied activities, KKL-JNF has found that integrating cultural landscape and ecosystem services approaches is a powerful tool in order to guide management activities of functional rehabilitation, such as water redistribution in a specific landscape unit. The ability to display ecosystem services for different land use within a

Images: Mott Kaplan (left); Albatross – KKL Archive (right)

Green belts planted around cities and villages and along dry streams provide recreation and leisure sites for inhabitants

cultural landscape perspective is an important advantage of the integrated approach. The integrated approach provides a useful understanding of the cultural inputs, outputs and services in the context of ecosystem and landscape function. We suggest that this approach is particularly useful for environments heavily influenced by humans, for example in heavily grazed drylands.

Linking both ecosystem services and cultural landscape frameworks enables concentration on the human dimension of ecosystems and landscapes management, thus enabling the integration of rehabilitation interventions within a multifunctional landscape, including agricultural and urban ecosystems. The two frameworks are complementary in providing guidelines for combating desertification and together have proven successful in adding unique ecosystem services to the cultural landscape of the Northern Negev.

An evaluation of results from the functional rehabilitation of Northern Negev ecosystems, from the perspective of the cultural landscape-ecosystem services approach, indicates an increase in the diversity and level of ecosystem services supplied to humans. These ecosystem services comprise all types of services including:

- Regulating services, which regulate the water cycle to prevent resource loss and mitigate flood damages; regulate and prevent soil erosion; protect arable land, grazing land and urban areas from flooding and erosion; increase primary productivity as a driver in the ecosystem's energy and nutrient cycles; support populations of natural enemies of agricultural pests; regulate pollination services; and regulate carbon cycling through increased rates of carbon sequestration.
- Cultural services, which improve the life quality of inhabitants: the green belts planted around cities and villages and along dry streams supply recreation and leisure sites, native flowering sites, bicycle trails, parks and community forests. Rehabilitation of the ancient agriculture sites enables the preservation of historical and cultural heritage assets and supports forest-based tourism, thus encouraging visitors to use guest facilities at neighbouring communities and making an economic contribution to rural livelihoods.
- Provisioning services, which supply biomass and shade for sheep, goat and cattle herds owned by the local population, and supply firewood to the local population for cooking and home heating.

In conclusion, KKL-JNF's work in the functional rehabilitation of Northern Negev ecosystems provides an important contribution to the world's understanding of desertification and rehabilitation processes and the importance of an active multi-use approach to land management.

KKL-JNF's methods for the functional rehabilitation of Northern Negev ecosystems can be used as efficient and applied tools to rehabilitate desertified areas outside Israel, as well as for adapting to the expected influences of global climate change in water-limited regions.

KKL-JNF shares with other countries the scientific basis, applications and adaptations of its methodology for the return of functionality to degraded ecosystems, which are supported by long-term monitoring and research programmes. Results of the rehabilitative actions and management of rehabilitated areas are evaluated by their long-term effects and influences. Recent studies assessing the effects of decades-old rehabilitation works show that rehabilitation processes contribute to increased ecosystem integrity and functionality.