With the support
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This publication is the result of the project *Community Action for Improved Drought Response and Resilience – CAIDRR* (SHARE – KENYA) funded by European Union (reference: FED/2014/349-712). Partnership Agreement VSF-Germany (Grantee) and Water Right Foundation (WRF) (Partner) of the 27/01/2015 'Conservation and Reconstruction of the Oasis Ecosystem of Loiyangalani Project to Combat Desertification and for Water Resources Management, 2015- 2018'.

Lake Turkana is something more than a unique and distinctive place, it is an emotion which derives from the elements, from the almost barren soil, from the water and the light which blend into wide expanses without signs of human presence, except those from the most ancient historical times. It is a continuous emotion which comes from these simple elements, clean-cut, without any twists or bends, except those of the shapes they have acquired over millennia from the wind, erosion, and great geological transformations. In this land the sign of man is primordial, it is truly at its origins as 'man'; it is from here that all the men that populate the Earth began.
The men and animals who roamed this region in those ancient times lived in a very different environment, rich in resources, generally humid, with a temperate climate and which provided abundant food to our human ancestors. Lake Turkana is located today in an extremely desolate area, with wide expanses of volcanic rock with isolated and lean acacias. It is more than a lake, it is almost an inner sea; the high degree of evaporation and the periods of drought over the past few centuries have modified its appearance, yet it is still the world's largest permanent lake in a desert area, but with strong alkaline waters not god for the human health.
Yet, despite these difficult environmental conditions, many different ethnic groups still live in this area in some oasis and/or in areas with available underground water. Preserving and enhancing the state of the environment in which they live is thus a fundamental aspect for the survival of these people. And it is not a question only of their survival in view of the growing desertification, but also regards their forced immigration toward other areas in the region and other countries, which increases migration flows.
The *Oasis Ecosystem* project had an ambitious objective, that of reconstructing the habitat of the Oasis of Loiyangalani and triggering an *Oasis Effect* with the establishment of a sustainable virtuous circle aimed at inverting the *Desert Effect* which oppose the ongoing desertification process and faces the three main problems related to desertification, that is Water, Soil and Vegetation and using, wherever possible, local 'traditional knowledge' and food production with the awareness of the local people.

Lorenzo Vallerini, architect and landscape architect, is the Coordinator and Scientific Coordinator of the *Oasis Ecosystem* project. He taught Landscape Architecture at the DIDA-Department of Architecture of the University of Florence between 1990 and 2015. He has carried out research and projects at both the national and international level on topics related to landscape planning and design at various scales. During an intense professional activity that has lasted for over thirty years he has been involved in the drafting of plans and studies concerning the territory, the environmental insertion of large infrastructures and the design of parks and urban public spaces. He is the author of more than seventy publications and eight books (research, professional experiences and theoretical essays).

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THE ORIGINS OF THE EARTH AND MAN Oasis Ecosystem | Project to combat desertification and for management of water resources

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Lake Turkana, Loiyangalani, Marsabit County, North Kenya

by Lorenzo Vallerini

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This book is the result of the studies carried out in the Department of Architecture, University of Florence.
The volumes are subject to a qualitative process of acceptance and evaluation based on peer review,
which is entrusted to the Scientific Publications Committee of the Department of Architecture (DIDA) with blind review system. Furthermore, all publications are available on an open-access basis on the Internet, which not only favors their diffusion, but also fosters an effective evaluation from the entire international scientific community.

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Acknowledments Lorenzo Vallerini
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book cover
A view of Lake Turkana, approaching from Mt. Kulal (photo: L. Vallerini).

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with the collaboration of

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THE ORIGINS OF THE EARTH AND MAN

Oasis Ecosystem | Project to combat desertification and for management of water resources

Lake Turkana, Loiyangalani, Marsabit County, North Kenya

by
Lorenzo Vallerini

with the collaboration of
Giovanni Caponi,Giancarlo Ceccanti, Marco Folini Paolo Altemura, Marco Mazzoni, Piero Magazzini, Ugo Wolf

Content

Along the Lake Turkana going to the south.
(Photo: L. Vallerini).

I DINTORNI DEL LAGO RODOLFO DANNO UN'IDEA ABBASTANZA PRECISA DI COME DOVEVA ESSERE IL MONDO SUBITO DOPO LA CREAZIONE DEL CIELO E DELLA TERRA, SECONDO LE PAROLE DELLA GENESI: 'LA TERRA, PERÒ, ERA INFORME E VUOTA E SULLA FACCIA DELL'ABISSO ERANO LE TENEBRE' [...] E ALLORA NON SI VEDONO CHE ONDE E ONDE DI LAVA NERA PIETRIFICATE E RAPPRESE, CON LE CRESTE IMMOBILMENTE, DRAMMATICAMENTE IMPENNATE; E TRA UN'ONDA E L'ALTRA, BURRONI PROFONDI PIENI DI MAGMA SBRICIOLATO [...] COSÌ ARRIVARE AL LAGO RODOLFO, ANCORA OGGI, DÀ IL SENSO PERIGLIOSO E ACRE DI UN'ESPLORAZIONE INEDITA. CORRIAMO O MEGLIO CI AGGIRIAMO [...] IN QUESTO CAOS MAGMATICO, SOTTO UN CIELO INCENDIATO DA UN SOLE SPIETATO; ALLA FINE, QUANDO VEDIAMO ALLARGARSI TRA DUE PICCHI NERI E LUSTRANTI DI LAVA RAPPRESA, LA DISTESA VERDE GIADA DELLE ACQUE DEL LAGO.

A. Moravia, Lettere dal Sahara, 1981

Echoes from the past, traces of the future

An open landscape view from the aircraft. (Photo: L. Vallerini).

Mauro Perini

It is truly remarkable how the evolution of the 'LOIYANGALANI OASIS REHABILITATION SYSTEM' project, affectionately renamed by us the 'Vallerini Project', has in some sense gone hand by hand with that of the Water Right Foundation: with its aspirations, its transformations, its critical situations and its contents.

The project initiated many years ago with the funding of a study, the in-depth analysis of an idea, of a suggestion, almost. At a first glance it seemed a sort of exotic cooperation project, an anachronistic reminiscence of exploration voyages in tribal Africa.

The project underwent karstic phenomena, it disappeared and reappeared again, it went beyond the boundaries of the passionate reports of scholars and researchers, it met travelling companions, it widened its scope, established relationships and involved new actors.

The project put our organization to the test from many different points of view. It tested our habits, attitudes and methods; and more than once we felt that we had embarked on a journey that was too complex and difficult for our small boat, which was not yet ready to navigate these high waters on its own.

And the place itself is fascinating, a place like few others, inaccessible, remote, unknown.

Can we manage so much complexity from our headquarters in via Villamagna?

Passion and stubbornness were among the main ingredients that allowed us to go forward, to overcome new and unexpected obstacles, that and a growing trust and appreciation that had been established and was developing between our Foundation, the founding members and the municipalities in the region that believed in the initiative and strengthened the foundations for consolidating and developing the activities derived from the so-called 'Vallerini project'.

As the years went by we all became familiar with the increasingly topical and central issues and organisations related to the Turkana project: the right to water and the combat against desertification, opposition and resilience in the face of climate change, as well as coordinated actions for a local sustainable development, and finally discovering that in the local language Loiyangalani means 'place of trees': almost a symbolical recognition of affinity between our intentions and vocations now that our Foundation is placing trees and their material and symbolic importance at the centre of its strategic programme in terms of a permanent guideline that involves public and private as well as local and international actors in a constant restating of the values that were at the basis of the Declaration of Rio de Janeiro of 1992, 'OUR COMMON FUTURE', and which is in need today, more than ever, of widespread, replicable and 'uninterested' actions for opposing the effects of global warming.

A cooperation for development which is strongly based on environmental themes linked to both historical and biological time frames, and which is promoting – from a variety of perspectives – the urgent need for another possible world.

A cry that comes from the Earth, a warning that reaches us from the future: to pay heed and respond to them with exemplary interventions in those windy and inhospitable expanses, where ethnologists and archaeologists have retraced the origin of human life, confers to this convergence of events unexpected and hopefully long-term meanings.

We cannot hide the fact that we live in dark times: the combination of economic crisis and ethical-social decadence can have harmful effects. We need positive actions. Concrete demonstrations. Lessons learned and to be learned.

I wish to personally thank all of the people who worked to make this project possible, identifying – with a more careful and conscious observation – echoes from the past and traces of the future.

Mauro Perini
President of the Water Right Foundation

The development project. Community Action for Improved Drought Resilience (CAIDR)

Goats at grazing along the lake in an area characterised by a strong loss of the herbaceous layer due to excess grazing and erosion. (Photo: L. Vallerini).

Maurice K. Kiboye

Vétérinaires Sans Frontières Germany (VSF-G) is an International Non-Governmental Organization (INGO) whose mission is to improve the welfare of vulnerable populations in developing countries, providing humanitarian and development assistance to pastoralists and vulnerable communities in areas where livestock is of importance. The goal of the organization is to assist local communities with special focus on livestock farming to increase contribution of livestock to household food security and economy. The organization's vision is that people in developing countries whose livelihood depends on livestock live a self-determined and decent life in co-existence with their livestock and their environment.

VSF-G has 20 years of experience implementing short and long-term programmes with pastoralists in the Horn of Africa. In the region, the organization implements programmes which focus on Livestock, food security and Livelihoods, Natural Resources Management, Peace and Conflict, Good governance, Disasters & Emergency, and Agriculture sectors. The aim is to draw synergy from all sectors that support livestock as productive asset of the grass root community. Current VSF-G programmes are in Southern Sudan, Northern Sudan, Kenya, Somalia, and Ethiopia.

The strategy for Kenya aims to improve the food security and livelihoods in Northern Kenya through strengthened livestock health, production, livestock trade, economic empowerment, holistic natural resources management, Disaster Risk Management (DRM) and resilience building using a community driven and climate change adaptive approaches.

VSFG started its programmes in Northern Kenya in 2003 in the Turkana/Toposa borders of the Karamoja Cluster and over the years expanded its operations to cover the Marsabit/Omorate borders in the South Omo Cluster.

In its humanitarian and development programmes in Kenya, VSFG is a recipient of funds from various institutional donors including European Union,(EC, ECHO),USAID,BMZ and the UN Agencies (OCHA, UNDP, FAO) to mention but a few. For development programmes, one of the major donors to VSFG operations has been European Union (EU) through its various funding frameworks such as EDF, Europe Aid and SAHRE. These grants have enabled the organization to make impressive achievements in Animal Health, Food Security, Agriculture, Income Generation, Drought Preparedness and Response, WASH, livestock infrastructure & marketing, Peace building, Research, pastoral radio programmes and Support of the public institutions as well as support of private sector. Since 2003, the contribution of EU towards VSFG programmes in Northern Kenya is about Euro 9.5 M.

Over the last three (3) years, EU has been funding development project, *Community Action for Improved Drought Resilience (CAIDR),* with a total investment of *€2,055,166,* in Northern Kenya.The project interventions focused on Disaster Risk Reduction (DRR), Livelihoods and Water sectors. The approaches in implementing activities of each sector varied. The DRR activities focused on building of local capacities and systems for preparedness, management and response actions towards assets protection at community and county government levels using Community Managed Disaster Risk Reduction (CMDRR) and Pastoral Field Schools (PFS) approaches. Livelihoods activities focused on improving access to services and management of livelihood resources and assets through strengthened and diversified livelihoods systems, natural resources management using climate smart technology (drip irrigation, shed farming, agroforestry),fishing, poultry production),income generation through Village Community Bank (VICOBA) and networking. Water activities mainly focused on Conservation and reconstruction Oasis ecosystem in Loiyangalani; community awareness, promoting access to water and fodder production.

The outcome of these divergent activities of the project were geared towards promoting pastoralism as a viable production system in an environment plagued with recurrent drought, based on the under-

A man along the Lake Turkana at Sibiloi National Park. (Photo: L. Vallerini).

standing that livestock is one of the most resilient productive assets in the Arid and Semi-Arid Lands (ASAL) in Northern Kenya. A number of approaches adopted by the project were innovative and their implementation involved cross-contribution of knowledge and learning between communities and the project implementers. This was geared towards influencing policy in designing of similar programmes for pastoral development.

The project targeted and directly benefited 15,000 individuals (pastoralists, pastoralist drop-outs, customary authorities, county government employees, traders, CBOs) who had day-to-day interaction with the project in the implementation and monitoring. The project was estimated to have benefited approximately 110,000 inhabitants of Marsabit County who interacted with the direct beneficiaries in one way or the other.

The project adopted resilience building strategy in its implementation where target direct beneficiaries were cliff hungers who required support in order not to slip into crisis, rather than the poor households who were receiving support through humanitarian programmes such as Hunger Safety Net Programme (HNSP) to meet basic needs. The implementing partners adopted community based targeting using the outcome (data and information) of a Household Economic Analysis (HEA) conducted during the inception phase of the project. The delivery of the activities employed participatory methodologies, capacity building (skills transfer and mentorship) and mainstreaming of gender and DONO Harm at all levels of project activities.

The project was implemented in a Consortium of three Non-Governmental Organizations (NGO); VSF-Germany (lead), Water Right Foundation (WRF), Italy, and Community Initiative Facilitation & Assistance (CIFA) –Kenya, each of which received direct funding from EU for the action.

Water Right Foundation has been implementing water related development projects, promoting development cooperation projects, information and awareness activities on 'access-to-water' right and sustainable management of the resource, environmental education activities in schools, research projects with the University of Florence, training for the maintenance of infrastructures built with the support from local municipalities, the civil society and the scientific and academic partners. Since 2005, WRF has co-financed 30 small-to-medium scale projects to a tune of €2,450,000 with funds from a local Fund called 'L'Acqua è di tutti' created by local Municipalities. In the CAIDR project, WRF was directly responsible for implementation of water component.

Community Facilitation and Assistance (CIFA) is a Kenyan NGO that has been in operation since 2000 and operates in Marsabit, Moyale and Southern Ethiopia where it has been implementing cross border programmes. CIFA has a wealth of experience in pastoral development in Northern Kenya and is implementing activities in livestock water, Natural resource management, livelihood diversification, peace building and conflict management and education sectors. In the CAIDR Project, CIFA implemented activities in the livelihood sectors.

Throughout the project implementation, the consortium sustained a strong collaboration with relevant government ministries and departments at County and National levels. The aim was to ensure takeover and technical support of communities from local actors for sustainability of the project achievements beyond the project life. The government Ministries included Agriculture, Livestock and Fisheries Development, Water, Environment and Natural Resources, Gender and Youth Development. Other institutions included National Drought Management Authority (NDMA), Kenya Agriculture and Livestock Research Organization (KALRO), Kenya Wildlife Service (KWS) and Kenya Forestry Service (KFS). NDMA played a key role in coordination of implementation of the project activities and linkage with EU at Nairobi level.

OVERVIEW

A view of the Turkana Lake from the aircraft. (Photo: G. Ceccanti).


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The features of a sustainable habitat

Settlements of the Turkana Village out of the Oasis. (Photo: L. Vallerini).

Saverio Mecca

The 'Loiyangalani Oasis Rehabilitation Ecosystem' project tackles one of the most relevant issues that will be at the centre of the concerns of future generations, the water and the natural resources, and, at the same time, show us how important are sustainability and resilience for the communities and for the projects we are going to conceive and realize.

In recent years the evidence of human-initiated climate change has already began to transform human habitats. The most pronounced changes occur as in cities under the negative outcomes of rapid urbanisation, consumption of natural resources and demographic changes, as, and may be more dramatically, in areas close to desert areas and involved in desertification processes.

Mitigating the impacts of changing environmental conditions is one of the major challenges of today's communities. In this context the concept of 'resilience' has become important as a systemic concept able of increasing the ability of adaptation of human settlements in the face of changes: 'resilience', in urban science, describes the capacity of human habitats to absorb shocks and perturbations without undergoing major alterations in its functional, physical, social and economic systems. A crucial feature of a resilient environmental system is having the ability to survive the potential risks and threats as well as taking advantage of the positive outcomes that the disturbances bring. The resilience of an ecosystem has firstly defined by Holling (Resilience and Stability of Ecological Systems, 1973) as "the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes".

A human habitat can be truly sustainable only if it can manage to establish a balance between the changing conditions while maintaining its indigenous characteristics by rebuilding new systems in order to respond to forthcoming changes. The features of a sustainable habitat substantially coincide with the requirements of a resilient system in environmental, socio-cultural and socio-economic terms.

Therefore the two concepts, 'sustainability' and 'resilience', are inseparable and vital for the survival of human settlements in changing environments. Responding to the requirements of both sustainability and resilience will strengthen the different territories in the face of forthcoming climatic, environmental, socio-cultural and socio-economic changes.

Vernacular cultural heritage, which is in continuous evolution, constitutes a substantial research field with its immense adapting capacity to the changing external circumstances. The understanding of resilience sees the environment in constant transformation; therefore resilient system design presupposes a dynamic system, which is primarily characterised by flexibility and adaptability.

In this case, vernacular cultural heritage, which includes in its origins a series of responses to the changing dynamic factors such as micro-climate, local materials and local living cultures, can meet the requirements of resilience.

In the framework of 'sustainability', which deals with the scarcity of natural resources and economic crisis, 'resilience' emerges as a 'complementary' key approach. In comparison with the concept of 'sustainability', 'resilience' is a more dynamic notion as it refers to 'transformation', 'flexibility' and 'adaptation' of the systems through changing circumstances while 'sustainability' is mostly concerned with sustaining the 'stability' without requiring re-adaptation. However resilience seems to have an opposite sense in this respect to sustainability, and although they both focus on maintaining the system's equilibrium, they do it in different ways.

The close relationship between vernacular cultural heritage and resilience was first noticed in the definition by Paul Oliver (Encyclopaedia of Vernacular Architecture of the World: Cultures and habitats, 1997):

> vernacular dwellings and buildings are related to their environmental context and available resources, they are customarily owner or community built, utilizing traditional technologies. All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of living of the cultures that produce them.

The natural amphitheatre of Gof Sokorte Guda, with its 150m high caldera, shelters the freshman lake known as Lake Paradise. (Photo: L. Vallerini).

Oliver's description points out the existence of numerous parameters in the constitution of a local building culture, above all the role of the 'micro-climate' and various environmental conditions.

Vernacular cultural heritage is characterized by three specific factors that are relevant for resilience:

- interaction with climate change and changing socio-cultural conditions;
- interaction with a certain environment after a certain time frame;
- being a socially shared knowledge.

Therefore, indigenous knowledge and vernacular culture become very specific and localized and can represent the specific responses given in the pre-industrialization age by human beings to environmental, socio-cultural and economic challenges by processing available natural resources for their survival.

Indigenous knowledge refers to the methods and experiences selected and established by local communities from a progressive understanding of the local resources, constraints, values and risks over the years. The most relevant character of indigenous knowledge, which distinguishes it from other categories of culture, is that of being diffused informally and developed/transmitted collectively over generations: accumulated practices have not been experimented in a systematic and scientific way over the years, since they are mostly a series of social and shared values that are transmitted from one generation to the next. Looking for sustainable design paths for future human settlements, we can rely on past findings for developing resilient planning strategies, analysing, selecting, testing and verifying the intangible heritage of vernacular environmental culture. In this way the heritage of vernacular culture can provide a rich field of research concerned with developing new strategies of resilience, meant as the shock-absorbing capacity of systems aiming towards sustainability in a world of changes and transformations.

In a given society, the existence of a local culture implies a favourable development of awareness that arises from diffused cultures.

Indigenous knowledge plays an important role in the way communities deal with crises, disasters and profound changes. In this case the concept of 'resilience' becomes important for developing an approach to adaptation through a series of strategies by which the inhabitants use available resources to cope with adverse conditions that can occur due to the disasters. Resilience attributes to an ecosystem the ability to repair damages after a disaster, as well as to absorb impacts and manage emergencies together with the capacity to adapt and innovate in socio-territorial organization. Strengthening the resilience enables communities to develop a great capacity to mitigate the effects of natural hazards.

Traditional knowledge, which is achieved through experiences and intergenerational transmission, strengthens social-ecological systems as a result of its ability to deal with complexity and uncertainty.

The origins of the Earth and man

On the road to the lake. (Photo: L. Vallerini).

Lorenzo Vallerini

Lake Turkana is something more than a unique and distinctive place, it is an emotion which derives from the elements, from the almost barren soil, from the water and the light which blend into wide expanses without signs of human presence, except those from the most ancient historical times. It is a continuous emotion which comes from these simple elements, clean-cut, without any twists or bends, except those of the shapes they have acquired over millennia from the wind, erosion, and great geological transformations. In this land the sign of man is primordial, it is truly at its origins as 'man'; it is from here that all the people that populate the Earth began. Genetic research has proven with a great degree of accuracy that all humans have a common origin, and that this common origin, regardless of the colour of the skin, lies precisely in the first men that lived in the area of Turkana, south Ethiopia and south Sudan, who then spread out throughout the Earth[1 2]. This generates a timeless emotion that runs through the visitor, making him love this place for its total simplicity and its great beauty.

In 2009, the one and ~~a~~ half million-year-old footprints of a human biped, surprisingly similar to modern man, were found, clearly standing out in the volcanic soil, at the Sibiloi National Park[3] along the north-eastern shores of lake Turkana[4]. The first step of mankind therefore seems to have been made in this area; and other findings of fossils and tools have confirmed this early dating.

The men and animals who roamed this region in those ancient times lived in a very different environment, rich in resources, generally humid, with a temperate climate and which provided abundant food to our human ancestors.

Lake Turkana (named lake Rudolf in the past, in honour of the Austro-Hungarian Prince Rudolf of Hapsburg-Lorraine by the explorers Samuel Teleki and Ludwig von Höhnel, who were the first Europeans to reach its shores in 1888) is located today in an extremely desolate area, with wide expanses of volcanic rock with isolated and lean acacias.

Fig. 1 Fossil footprint at Ileret. (Source: http://bit.ly/2n29FaG).

Fig. 2 Lake Turkana in the Rift Valley. (Source: GEO 123 – Lake Turkana National Parks).

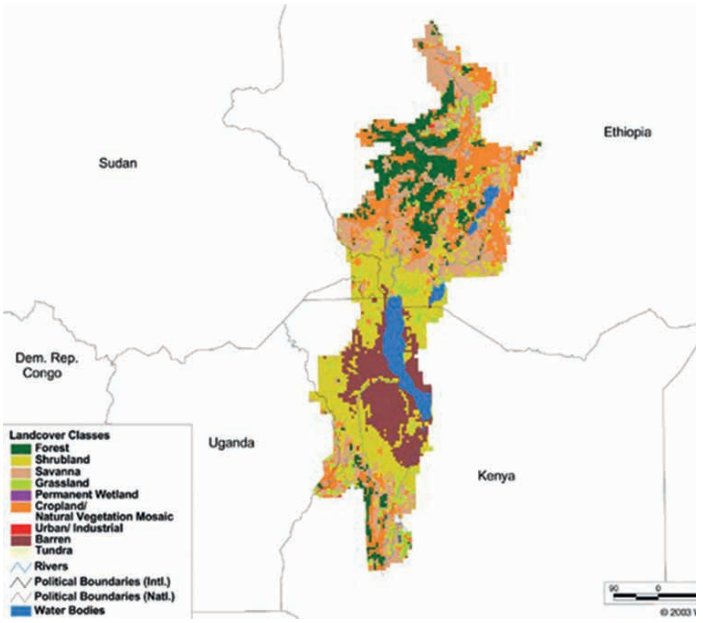


Fig. 3 Land cover of the Turkana hydrographic basin with the barren lands highlighted. (Source: 2003 World Resource Institute).

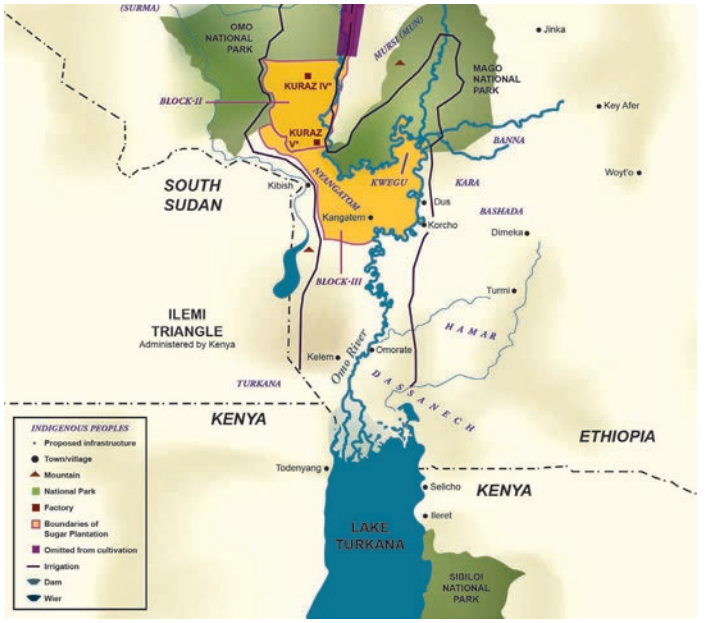


Fig. 4 The uplands in Etiophia where the Omo River flows towards the Lake Turkana.

> Waves and waves of black petrified lava, clotted with their motionless crests dramatically raised [...] and between one wave and the next deep gullies full with crumbling magma. [...] Thus reaching lake Rudolf even today seems to transmit the dangerous and acrid sense of a new exploration.[5] Alberto Moravia, *La ragazza di Baragoi*

Situated in the Rift Valley, in the north-west of Kenya, it covers an area of 6,405 km², almost entirely within the borders of Kenya; only the northern section, in the region of the delta of the river Omo, is located in Ethiopia.

With a length of 257 km, a width of approximately 31 km, and a maximum depth of 73 m, lake Turkana is more than a lake, it is almost an inner sea; the high degree of evaporation rate and the periods of drought over the past few centuries have modified its appearance, yet it is still the world's largest permanent lake in a desert area.

In fact, although its origins go back to the Miocene, with a maximum expansion in the period between 9-7000 years B.C., when it covered the entire Lokitipi plain[6] until the Nile to the west (this is the reason why Nilotic fauna is still found in the lake), with the passing of time the lake shrank, and continues to do so in the present, which increases the concentration of salts both in its waters and in the soil. This explains the high level of alkalinity of the waters, which have a high level of sodium carbonate. Its only important affluent (90% of the water supply), with the exception of two seasonal waterways (rivers Kerio and Turkwell), is the river Omo, which comes from the Ethiopian plateaus, carrying with it also large amounts of silt and sediments. The envisaged building of additional dams on the Omo in Ethiopia and the irrigation systems for the large sugar cane plantations in the valley of the Omo river could reduce the supply of water even more, which would result in a serious risk for the already delicate balance of the lake's ecosystem.

The area of lake Turkana is located in two counties, Turkana County to the west, near the border of South Sudan, and Marsabit County[7] to the east, near the Ethiopian border, in a region mostly characterised by arid and semi-arid zones and very sparsely inhabited (with a density of approximately two inhabitants per km², with maximum densities of seventeen in the most fertile areas and of one in the most arid ones) and with a haphazard road system, with the exception of the main thoroughfare, the A2, which connects Nairobi to the south with Moyale and then continues on into Ethiopia.

From the geological point of view the land is characterised by volcanic rock which is part of the vast lava field that extend from lake Turkana to the north. Many mountains are in fact of volcanic origin, such as Mount Kulal (with an altitude of 2,200 m.) and the mountains of Marsabit (1,800 m.) and Ndoto-Ngiro (2,600-2,800 m.). However, most of the land is characterised by extensive and wavy plains with average elevations between 530-760 metres above sea-level. The Desert of Chalbi to the east forms instead a vast depression which covers almost 1,000 km², whereas the remaining territories, except for those around Moyale, which are very fertile, are very acid or saline, like the Desert of Chalbi, and therefore completely inadequate

Fig. 5 Barren Lands. (Photo: L. Vallerini).

Fig. 6 Lake Turkana and the South Island National Park one of the world's largest concentrations of crocodiles. (Photo: L. Vallerini).

for any form of cultivation. The only greenery is a spontaneous vegetation which is barely sufficient for shepherding.

In this context water is evidently a problem, and the entire region, except for the mountainous areas (eco-climatic zone of mountainous forests), is arid, with scarce rainfall, which characterise most of the region as semi-desertic eco-climatic zones.

These soils, poor and arid, are degraded to such an extent that their regeneration is at stake. This is the result of their alteration by human activities (shepherding), in addition to global warming and the resulting droughts, which are increasingly prolonged and repeated. The need for fuel and for pastures (resulting as well from the increase in livestock) continue to prevent the regeneration of the vegetation. Desertification is thus becoming an irreversible process.

The entire region and the basin of lake Turkana are characterised by arid and semi-arid lands. The ongoing process of desertification is bringing about a gradual and irreversible reduction in the capacity of the soil to produce the resources and services on which the populations that live on the shores of the lake and in the entire region depend. In this place, perhaps more than in any other, food, water and land represent the elements on which the life of these people depends.

Yet, despite these difficult environmental conditions, many different ethnic groups still live in this area. The two dominant groups are the Turkana and the Samburu, whereas the Rendille's numbers have decreased over the years, as well as the El Molo, of which only a few dozen individuals are left and who are the only group that lives off fishing in the lake. The Gabbra and the Borana live to the north and the east. All groups, except for the El Molo, live from livestock farming, although recent initiatives with the participation of international cooperation have been aimed at fostering fishing in the lake.

Preserving and enhancing the state of the environment in which they live is thus a fundamental aspect for the survival of these ethnic groups, that until quite recently were fighting against each other for the few resources available.

And it is not a question only of their survival in view of the growing desertification, but also regards their forced immigration toward other areas in the region and other countries, which increases migration flows, which already represent a problem for developed countries, and finally the loss of their cultural identity and the abandonment of their wide expanses to the progressive process of decay.

The Global Risk Report carried out annually by the *World Economic Forum*[8], clearly highlighted, both in 2016 and in 2017, with the support of most of the world scientific community, how the climate is becoming increasingly hostile and how this is greatly due to the activities of mankind, and finally how climate change is now 'perceived' as one of the main threats to social and economic stability, and more generally, to our very life on Earth. Additionally, also the interconnections between the various risks are underlined:

> It is evident that climate change can contribute to a large scale increase in immigration, forcing entire populations to flee one region in order to find better conditions in another. And the same connection can be made between scarcity of water resources, epidemics, a natural

Fig. 7 Lake Logipi and flamingos. (Source: http://bit.ly/2G0AapL).

Fig. 8 Volcanic landscapes at the southern part of the lake. (Photo: L. Vallerini).

> catastrophe [...] climate change [...] tops the list of problems [...] during the coming eighteen months the main risk derives from involuntary migration [...] of peoples forced to leave their own lands as a consequence of war, misery, political instability; for the following ten years the main risk is related to water.[9]

One of the contributions to this book, *The landscapes of eco-poverty*, discusses and highlights with scientific data how these interconnections between climatic changes, a bad use of resources, first of all water, social instability and war, with the resulting mass-migrations, are all closely interrelated factors[10].

War in South Sudan, the serious case of drought and the resulting famine which affected Somalia, the south of Ethiopia and north of Kenya in 2017, forced thousands of people to flee their lands in search of shelter in other places, or even in refugee camps, often worsening the situation in the regions they immigrate to due to an excess of human pressure. The Oasis of Loiyangalani itself went, over a few years, from 1000 to over 5000 inhabitants, and the numbers are increasing due to the arrival of more people attracted by a place which still has water and some greenery.

A report from the international organisation Human Rights Watch from 2015[11] on climate change and the influence that it has on the life of the populations that inhabit Turkana County highlights how between 1967 and 2012 the average maximum and minimum temperatures have increased by 2-3 degrees, and how the seasons have changed with an altered distribution of rainfall, with the same low annual levels, yet concentrated in brief periods. Among the main consequences is that the wells in the riverbeds dry up very quickly and that famine has turned shepherds who lost everything into refugees. This land, in more recent historical times was certainly not rich and fertile, yet the vastness of the spaces and the low density of population, together with a delicate balance that is characteristic of arid regions, managed to ensure good living conditions for its inhabitants, the preservation of their traditions and cultural identity, and prospects for development which were still compatible with the environment.

Today, however, something in this balance seems to have broken, in part due to climate change, and there seems to be no alternative other than finding different forms of development, economic activities which are no longer only related to shepherding and harvesting, new ways of producing energy and of implementing knowledge linked to agriculture and the conservation of the resources which are still available, such as water, and in sufficient quantities for an increasing population.

Whereas on a global level the issue of climate change needs complex and interconnected policies, at the local level the keyword is 'adaptation' to the ongoing changes; yet here the initial environmental conditions are difficult and the time available for responding to critical issues seems to be shorter than in other parts of the world, thus a different model of survival, perhaps of development, is to be experimented, both from the operative and from a social and cultural point of view.

Fig. 9 The lake and a small village of fishermen. (Photo: L. Vallerini).
Fig. 10 Effects of desertification. (Photo: L. Vallerini).
Fig. 11 Turkana women. (Photo: L. Vallerini).

Figg. 11-12 Remains of human fossils of Australopithecus robustus, Homo habilis, Homo erectus and Homo sapiens at Koobi Fora Museum.
(Photos: L. Vallerini).

It is a question of 'closing the circle', that is of giving the opportunity to the people who live in these lands to be able to remain while maintaining their cultural identities, which are important also for the environments they live in, and of finding synergies between the production of food and the fight against desertification, between the conservation of resources and new technologies that are adaptable to traditional knowledge.

Once again in these places which "provide a relatively accurate idea of how the world must have been just after the creation of the heavens and the earth"[12], man is at the centre of change, for good and for bad. At its origins when he left from here to expand throughout the world, and today maybe for providing an indication, a *road map* for facing a different future which will of necessity have to evolve towards a greater balance if it is to remain in the hands of men.

Our wish is that the three *esses* of the Turkana region, which has been defined as 'a land of stones, snakes and scorpions', may turn into a simple *Loiyangalani*, in other words, as the elders of the village remind us and translate for us, 'the place of trees'.

Endnotes

[1] Cattaneo M. 2014, *Datemi un DNA e vi spiegherò il mondo,* «La Repubblica», 8 June. "Fossils show that the modern *Homo sapiens* appeared 200,000 years ago in the plateaus of eastern Africa. Geneticists agree. Human beings derive probably from a single small tribe of hunters-gatherers, perhaps a bit more intelligent and more advanced linguistically".

[2] The *Genographic Project*, launched on 13 April 2005 by the *National Geographic Society* and IBM is a multi-year genetic anthropology study that aims to map historical human migration patterns by collecting and analyzing DNA samples. As of 2017, over 890,000 participants in over 140 countries have joined the project. https://genographic.nationalgeographic.com/

[3] There are two important protected areas in Marsabit County: the Marsabit National Reserve, the Sibiloi Central and South Island National Park. While the first is a vast forest that stands like an oasis, rich in water with three volcanic lakes which constitute the ideal habitat of a large variety of fauna, the second consists of two islands in lake Turkana which are full of crocodiles, but mostly of an enormous semi-desertic area to the north of the lake – a Koobi Fora-Ileret – created for protecting turtles, fish and thousands of flamingos, pelicans and other water birds, as well as prehistoric and paleo ethnologic sites where more than 4,000 fossils of mammals and stone age tools have been found, in addition to more than 160 fossil remains of early humans from more than three million years ago: man was born here.

[4] Bennett M.R., Harris J.W.K., Richmond B.G., Braun D.R., Mbua E., Kiura P., Olago D., Kibunjia M., Omuombo C., Behrensmeyer A. K., Huddart D., Gonzalez S., 2009, *Early Hominin Foot Morphology Based on 1.5-Million-Year-Old Footprints from Ileret, Kenya*, «Science», vol. 323, no. 1197.

[5] Moravia A., 2007, *La ragazza di Baragoi,* in A. Moravia *Lettere dal Sahara*, Bompiani Editore, Milano.

[6] Wescott W. A., Stone D. M., Wigger S. T., 1995, *Geological and geophysical reconnaissance of the Lotikipi plain of northwestern Kenya and its relationship to the northern Kenya Rift*, «Journal of African Earth Sciences», vol. 21, no. 2, pp. 241-251. "The Lotikipi plain, located in the northwestern corner of Kenya, is a broad saucer-shaped depression surrounded by, and mainly filled by, volcanic rocks. Recently acquired geophysical surveys (gravity, magnetic, and seismic) show for the first time the structural configuration of this area and has resulted in an interpretation of its geological history within the framework of the evolution of the northern Kenya Rift. Two sub-basins have been recognized; the Lotikipi in the west and the Gatome in the east, separated by the Lokwanamoru range".

[7] Ony 5% of the region is cultivated and 80% of the population are shepherds. 20% of the population (approximately 17,000 people) live in the mountainous area of Marsabit, 9,000 of which live in the County's capital, Marsabit: the mild weather, good soil fertility and good communications contribute to attract population.

[8] The Global Risk Report, now in its 12th edition, is an annual report carried out by the World Economic Forum with the support of almost 750 experts on the impact and probability of the 30 greatest global risks, classified into 5 categories:

- Economic risks (unemployment; public and private fianancial crisis; deflation; financial bubbles; cost of energy, etc.);
- Environmental risks (extreme meteorological events; natural disasters; loss of bio-diversity, etc.);
- Geopolitical risks (terrorist attacks; state crises; failure of regional or global *governance,* etc.);
- Social risks (large-scale immigration; hydric crisis; food crisis; infectious diseases, etc.);
- Technological risks (*cyberattacks*; failure of I.T. infrastructure, etc.).

[9] Franceschini E., 2016, *Il pianeta: più caldo, più muri, più sete-I rischi per il mondo che verrà,* «La Repubblica», January, 12.

[10] Cianciullo A., 2016, *Clima e politica sono due volti della stessa crisi,* «La Repubblica», January, 12. In an interview to Pascal Acot, a climate historian, commenting on the conclusions of the Global Risk Report, he underlines the nexus between the long drought that devastated Syria between 2006 and 2011 and the destabilisation of the country which resulted in civil war "it was a textbook case, yet the effects of climate change is longer, more continuous. The fact that entire regions are overwhelmed by a violent change in the hydric cycle, that is a long dry season or an increase in floods, has created deep social upheavals that are having long-term consequences. And we must not forget that the process of 'global warming' is only getting worse".

[11] "There is No Time Left Climate Change, Environmental Threats, and Human Rights in Turkana County".

[12] Moravia A., op.cit.

The Landscapes of Eco-poverty

A view of Nairobi from the aircraft. (Photo: L. Vallerini).

Lorenzo Nofroni

In some recent publications the economist Edward B. Barbier has highlighted how, following the trajectory of the global processes in action, a perspective for the immediate future in which the whole of humanity, and not just one part of it, will be forced to face pressing choices conditioned by a new economic, social and cultural situation, that of the scarcity of environmental resources, is increasingly probable, a new epochal condition that the author has called the 'age of ecological scarcity'[1].

Compared to other times in the history of mankind, in the era of ecological scarcity economic growth, and with it also the improvement in the conditions of the poorer sectors of society, will not happen through the expansion of the boundaries of the exploitation of resources, since these limits have already been surpassed and a new era of coexistence with the phenomenon of the depletion of resources is underway.

During the past 50 years, ecosystems were modified faster and more extensively than in any previous period in human history, mostly in order to satisfy the growing demand for food, drinking water, wood, fibres and fuel. The result was a considerable drop in the economic benefits provided by ecosystems. According to the *Millennium Ecosystem Assessment*, approximately 60% of the main global ecosystem services were degraded or used in a non-sustainable way[2].

Poorer populations will be those to be hit harder by the continuous loss of these ecological services, in fact all over the world the poorer sectors of society live in ecologically fragile areas, often already subjected to various forms of environmental degradation, generated mostly by the richer and more powerful sectors of society[3].

Over 600 million people throughout the world live in rural areas, mountainous regions, forest systems and arid lands which are subjected to the degradation of the soil and water stress[4].

These populations survive with less than 1 US Dollar per day in conditions of extreme scarcity of resources, a scarcity which in time has been correlated to the atavistic condition of economic poverty, generating more incisive and deep forms of humanitarian crisis. These areas are also considered the most vulnerable to climatic and ecological disturbances, factors which foretell increasingly worsened scenarios.

The link between ecological scarcity and poverty

The link between ecological scarcity and poverty is an issue which has caught the attention of both academics and scientists, producing a series of studies and consolidated theoretical foundations. However, the appearance of the neologism, eco-poverty, or ecological poverty, a term expressing a key concept for addressing the issue from new perspectives, is in fact quite new.

The term eco-poverty introduces a new interpretative model which attempts to modify the exclusively economic meaning of the term poverty[5]. This terminological revision is made possible because of the phenomenon of the scarcity of resources obtained from ecosystems, which involves human populations not only in economic terms, but also ecological ones. Eco-poverty is thus presented as a more brutal and primitive form of deprivation, linked to the scarcity of environmental resources and caused by the difficulty of access to natural resources to produce environmental services essential for the sustenance of a population[6]. It manifests as the lack of basic natural resources necessary for the survival and development of human society[7]. Thus a population that lives in conditions of eco-poverty is influenced only marginally by variations in income measured in monetary terms, whereas it is extremely conditioned by the slightest variation in the conditions of the ecosystems in which it lives[8].

From this we can assume that a high value of ecological poverty determines any other form of deprivation and marginalisation, threatening any possibility of improving social and economic conditions of those who experience it.

Analysing the landscape for understanding the origins of eco-poverty

Real-life conditions in many regions show how the phenomenon of eco-poverty is a part of a complex system of interactions between social and environmental processes of an often destructive and harmful nature for the system itself. If the phenomena of eco-poverty are present in an area where the scarcity of environmental resources and economic poverty are combined, there must be a set of conditions which correlate phenomena of environmental systems degradation to those concerning social exclusion, usually considered as causes of scarcity and poverty.

The state of the landscape represents a strategic tool for enquiring in a single synthetic task, into the complex interactions between man and the environment.

Therefore, recursive relationship between scarcity of environmental resources and poverty defines the phenomenon called landscape of eco-poverty[9], this is, in other words, a condition resulting from the interaction between environmental degradation[10] and deprivation processes[11].

Using the concept of landscape of eco-poverty, it is possible to consider that the scarcity of environmental resources, derived from the processes of degradation of ecosystems, and poverty, with its wider implications due to social exclusion, are both components of a single interaction system.

If we consider the link between a society and its environment, we can identify and interpret the formal and process-related consequences of the said relationship in systemic terms, that is as social eco-social system (ESS)[12].

The landscape, as product and consequence of the interactions between a society and its environment, stands as an important indicator of the state of equilibrium of SES. This feature derives from the fact that every action, every process and every way through which a system develops, has implications on landscape. Also pressure factors affecting the various components of the system – among which the phenomena of environmental degradation and social marginalisation –, can be recognised and inquired upon through the respective implications on landscape, in other words through landscapes of eco-poverty.

The degenerative spiral involving environmental decay and social exclusion: the case of Syria

We can particularly clearly identify today with a special degree of clarity some cases in which the presence of eco-poverty phenomena have direct implications on the state of the equilibrium of the social ecological systems and which may be interpreted therefore through the landscapes that they have generated. For example, the series of environmental and social phenomena that characterised in the recent history of the north-east of Syria, during the period that preceded the 2011 civil war of, offers numerous elements for reflection.

The three governorates of Raqqa, Deir el-Zor and Hassakeh form the region which was called the 'breadbasket' of Syria, territories historically linked to the production of wheat and the extraction of oil. Despite the strategic and economic importance of the region, it was home to the poorest section of the Syrian population[13].

This area was affected by a series of interrelated phenomena which originated a degenerative 'short-circuit' at both the environmental and social levels, a spiral in which the scarcity of resources, the environmental degradation, the social disarticulation and iniquity certainly played a role in the determination of the crisis that led to the revolt against the regime. This degenerative condition emerged clarity during the droughts of 1988-93 and of 1998-2000. The Syrian government had always responded to the states of emergency with short-term strategies aimed mostly to controlling and if necessary repressing social revolts, therefore offering inadequate answers to the complexity of the phenomena and to the growing vulnerability of the region. The last drought that affected Syria during the period between 2005 and 2010, determined an impact which reached catastrophic dimensions with great human, economic, and environmental costs.

In fact, according to the Global Assessment Report on Disaster Risk Reduction (GAR 2013), during the five years of drought (2005-10), almost 75% of the Syrian agricultural production and approximately 86% of the livestock was lost. In particular, during the Winter of 2007-08, the average rainfall in all of Syria suffered a reduction of 66%, while in the north-east region of the country the phenomenon reached conditions never recorded before, with a total of 55 consecutive days without precipitation. In the governorates of Hassakeh, Deir ez-Zor and Raqqa, the effects of the long drought on the harvests of grain and other agricultural products was disastrous[14].

Fig. 1 The springs of the Ngobole Oasis or Oasis of the Moon: the increasing settlement pressure and the unregulated use of the springs, have rapidly reduced the available water resources. (Photo: L. Vallerini).

This calamity occurred during a serious political and economical crisis aggravated by the increase in the Syrian debt, the global financial crisis and the increase of food prices worldwide (especially grain). This forced the government to cut subsidies and raise the prices of fuel and fertilizers[15]. The condition began to worsen in 2010, when Syria had to import grain and other food products for the first time in 15 years. In the north-eastern region the convergence of economic crisis and environmental catastrophe led to the collapse of the production system, forcing approximately 50,000 families to abandon their lands[16].

The first revolts of 2011 in Raqqa and other cities of the north, which eventually turned into civil war, thus arrived at the end of a long process of weakening of social and environmental balances. As De Châtel[17] has noted, although the drought had effects on all the countries of the Middle East, the most catastrophic effects were registered in Syria, which may confirm the hypothesis of a strong relationship between the failure of the economic development model, the inefficiency of the actions undertaken by the government, the increase in the vulnerability to climate change, the greater impact of the calamity, and social and environmental fragility.

The Arab revolutions in the Middle East and in North Africa highlighted issues that previously had not been entirely explored. The scarcity of resources and the environmental and social security emerged as relevant issues, together with the usual interpretative models concerning global geo-politics and economics. It is therefore necessary to undertake research which focuses on the various social and environmental phenomena that can trigger degenerative conditions for populations and eco-systems leading to environmental and humanitarian crises which could sometimes be avoided.

The system of interactions and feedback: an interpretative model for landscapes of eco-poverty

From the scientific literature and through the observation of case studies, such as that of Syria, it is possible to suggest some hypotheses on the complex and interconnected nature of the phenomena that stem from the interaction between environmental decay and social exclusion and generate the landscapes of eco-poverty.

As previously stated, using the SES model it is possible to 'break-up' the image of a landscape according to its social and environmental components[18].

The condition of equilibrium of an SES depends on the balance between factors that determine creative interactions (as in organisational forces opposite to the disarticulation of the system) and factors that determine perturbative interactions or pressures (variations that can modify the evolution of the system itself, generating a greater fragility and a higher level of entropy). We can identify a condition of crisis of the system in which the landscapes of eco-poverty manifest, when the effects produced by the factors putting pressure on the system surpass the effects of the elements that play a contrasting or balancing role.

Based upon the same reasoning through which it is possible to subdivide an SES into systems and subsystems, it is also possible to de-

Fig. 2 Crop land in the Nairobi plateau: one of the areas with the highest density of crops in Kenya and numerous problems related to the intensive exploitation of environmental resources. (Photo: L. Vallerini).

structure the pressure factors linked to environmental decay and social exclusion and identify the articulation of their interactions.

It is thus possible to identify four groups of pressure factors:

- pressure generated by markets and economic processes combined with the absence or failure of governmental policies (PF1);
- demographic pressures combined with levels of consumption (or dependency from resources) and the technological level available (PF2);
- pressure generated by the reduction of the availability and the capacity of regeneration of resources (PF3);
- pressure generated by environmental calamities combined with the level of sensitivity and exposure of the system (PF4).

Pressure factors can effect not only the system to which they belong but also other subsystems, generating related phenomena with negative effects that have an effect on the entire SES. This creates the need to identify the interaction and feedback processes, that is the system of interactions that intervene as a result of the combination of various pressure factors.

The system of interactions was constructed on the main correlations underlined in the observation of specific case studies and with the results of the scientific research on the subject. The system is organised following six interaction processes[19].

The synoptic chart below presents a schematic synthesis of the matrix of interactions between pressure factors without, however, a hierarchy among combined factors, since in real life the interaction processes do not follow a direct causality, but rather a circular and recursive logic[20].

We refer to positive feedback regarding social fragility (R1) and positive feedback regarding environmental fragility (R6) in those cases in which conditions of social exclusion and environmental decay appear, produced mostly as a consequence of pressure coming from within the social or environmental components of a system[21]. These conditions occurred quite evidently both in the Syrian case and in other eco-social systems in the Middle East and in North Africa, such as Libya, Egypt[22] and Tunisia[23].

Interaction R2 can be defined as "iniquity in the access and use of resources". It is determined by the correlation of pressure factors that act on the government subsystem and on the subsystem of the production of resources, thus the absence or failure of policy, correlated to a condition of pressure that effects the capacity of the system to regenerate resources, can lead to an increase in the effects, not concerning the scarcity of resources, but also on the inevitable increase in social iniquity[24].

In the Syrian case this interaction is highlighted by the failure of the agricultural development policies imposed by the regime since coming to power. The model of development based on the intensive exploitation of environmental resources caused the impoverishment of the system of reproduction of resources, in particular regarding the use of groundwater and the preservation of the fertility of the

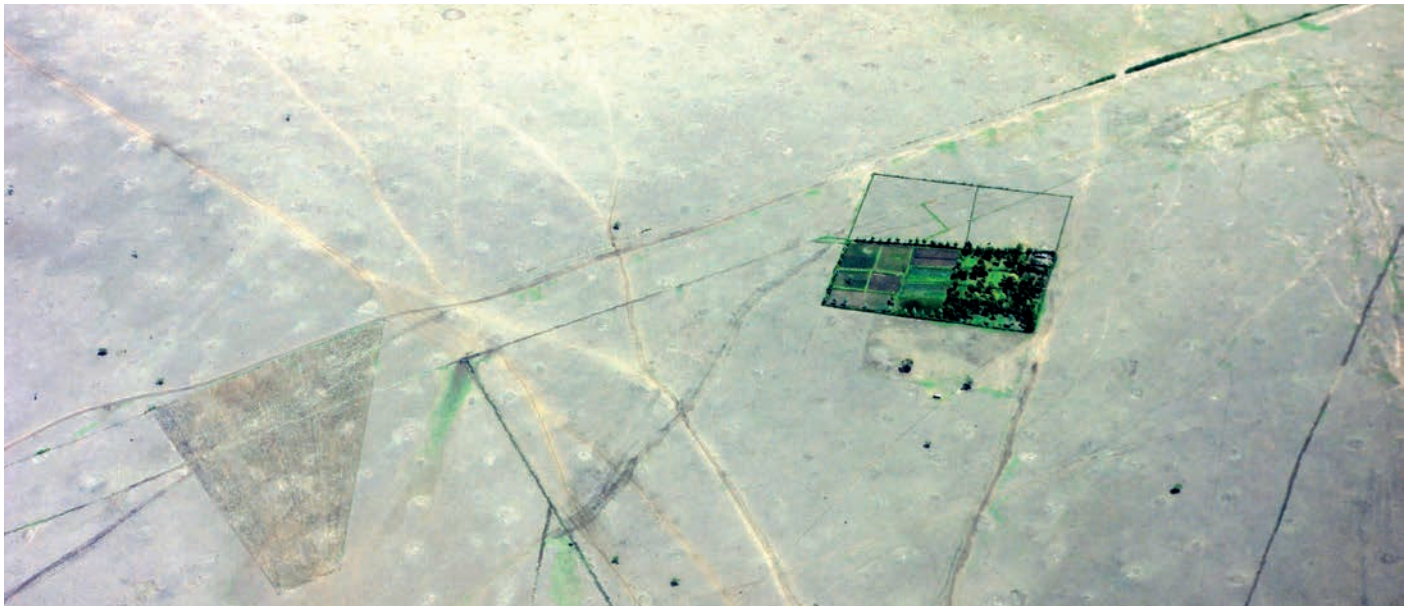


Fig. 3 Cultivated area in the arid zones of northern Kenya: the traditional and prudent use of environmental resources allows to develop a domestic economy sufficient to support the members of the settled community. (Photo: L. Vallerini).

soil. This policy determined the progressive increase in water consumption and in the degradation of the soil, exacerbating social conflicts due to the access and usage of resources in a social system in which corruption, lawlessness and abuse of power favoured both iniquity and discrimination.

The R2 interaction process is often linked to R3, that is the "impoverishment of environmental control and regulation systems"[25]. This interaction can be identified in all cases in which the reduction of collective and individual investments made to maintain the regulation and control of a territory make the system more exposed to exceptional climatic events, thus multiplying the risk of disasters and the impact of the phenomena. In the north-eastern region of Syria, the lack of investment of resources into long-term systems of control and regulation amplified the effects of the prolonged drought of 2005[26].

Interaction R4, "ecological-distributive conflicts and environmental segregation"[27], expresses the correlation between pressure from the cultural system and pressure from the factors of reproduction of resources. In this case, the destabilising feedback may derive from demographic pressure or from the levels of consumption of the population and induce effects on the availability of environmental resources. The Syrian case once more points clearly and evidently to the degenerative interaction between anthropic pressure and available resources.

In fact the deep environmental degradation, the incisiveness of the drought and the scarcity of hydric resources, as a consequence of the vulnerability of the system, and of the lack of tools for adaptability, determined enormous economic losses – especially for the weaker sectors of society which depended on agricultural production to support a domestic subsistence economy depending on state subsidies – and the consequent low prices of fuel and fertilizers. This series of events highlighted the presence of phenomena of environmental segregation affecting especially small communities of peasants, increasing distributive ecological conflicts on the appropriation of residual resources and the use of water reserves from tanks, barrages or dams.

Without the necessary provisions for a long-term solution of the problem, these areas of segregation and conflict were subjected to additional pressure linked to migration and the abandonment of the land, a phenomenon which often has negative effects, increasing the process of degradation of the soil, the loss of fertility and the increase in desertification, resulting in an "increase of the risk of calamity" (R5). This is the last of the processes identified, describing the interaction between factors of pressure from the subsystem of culture and the pressure from the subsystem of environmental control and regulation. In this type of interaction the change in climatic conditions or the reduction of the system of regulation of an ecosystem can intervene within a system that presents critical conditions regarding, for example, demographic and migration phenomena.

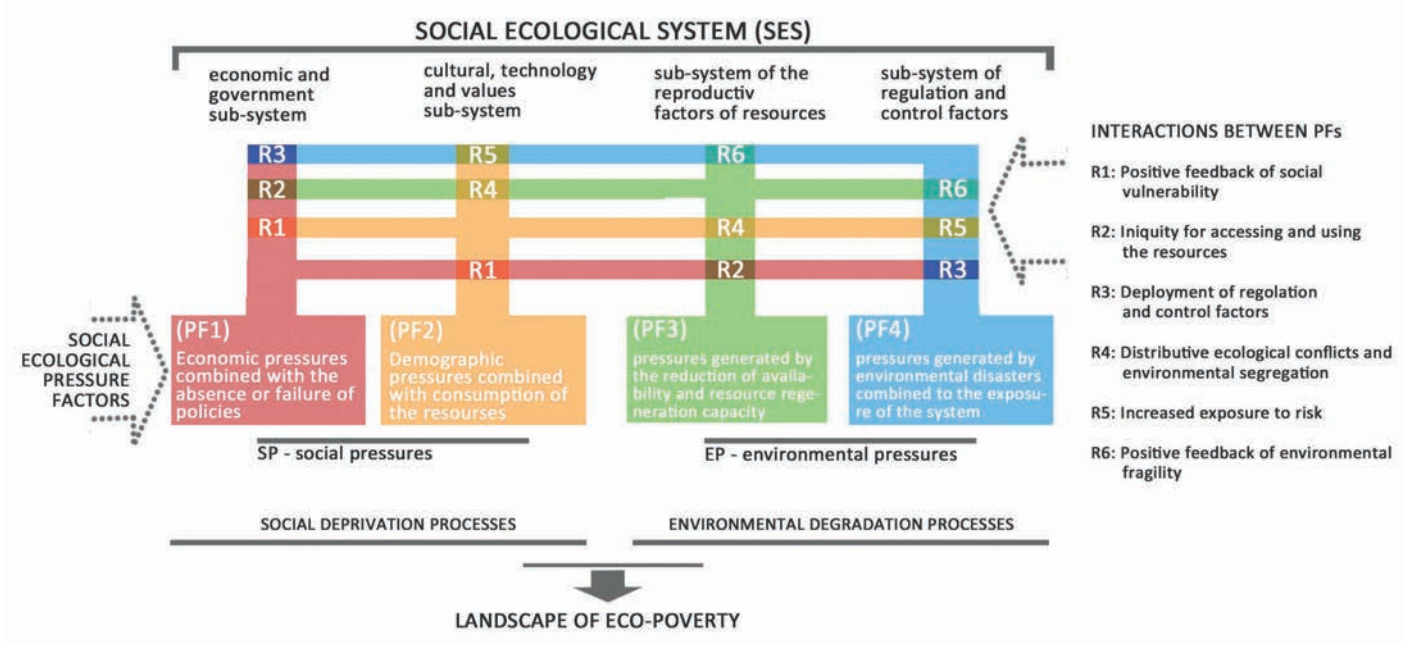

SOCIAL ECOLOGICAL SYSTEM (SES)
economic and government sub-system
cultural, technology and values sub-system
sub-system of the reproductiv factors of resources
sub-system of regulation and control factors
R3
R2
R1
R5
R4
R1
R6
R4
R2
R6
R5
R3
SOCIAL ECOLOGICAL PRESSURE FACTORS
(PF1)
Economic pressures combined with the absence or failure of policies
(PF2)
Demographic pressures combined with consumption of the resourses
(PF3)
pressures generated by the reduction of availa-bility and resource rege-neration capacity
(PF4)
pressures generated by environmental disasters combined to the exposu-re of the system
SP - social pressures
EP - environmental pressures
SOCIAL DEPRIVATION PROCESSES
ENVIRONMENTAL DEGRADATION PROCESSES
LANDSCAPE OF ECO-POVERTY
INTERACTIONS BETWEEN PFs
R1: Positive feedback of social vulnerability
R2: Iniquity for accessing and using the resources
R3: Deployment of regolation and control factors
R4: Distributive ecological conflicts and environmental segregation
R5: Increased exposure to risk
R6: Positive feedback of environmental fragility

Fig. 4 The logical framework of interactions between phenomena of social deprivation and environmental degradation. (L. Nofroni).

Fig. 5 Areas along the north part of Lake Turkana: this area has turned from a fertile plateau to arid area, anthropic action has undoubtedly been one of the most important components of the desertification process. (Photo: L. Vallerini).

The use of landscape planning as a strategic instrument for overcoming Eco-Poverty

As may be deduced from the logical frameworks and the Syrian case, the set of social and environmental pressure factors and of the relative interaction processes may contribute to a territorial condition in which environmental degradation and social exclusion emerge as predominant processes. As previously stated, the inquiry into the landscape is not only useful for determining critical factors, but may also indicate, through landscape planning, choices and systemic transformations that may contribute to achieving objectives of both an environmental and social nature.

Through the concept of the landscape of eco-poverty, it is possible to inquire into critical social and environmental phenomena in specific regional contexts using a new interpretative model.

The project for a landscape which is a consequence of all that has been said above will face a wide range of problems and situations; it may be combined with different types of interventions depending on the area of action: political, economic, cultural, environmental; it may adopt commensurate intervention scales, case by case, as appropriate to each problem; and will develop strategies that will be configured not only through direct actions on the territory and the forms of the landscape, but also through the establishment of cultural or economic processes that involve the communities in question.

Thus a project for a landscape that sets as its main objective the resolution of the problems generated by phenomena of eco-poverty must address subjects and solutions characterised by a hybrid nature which is also subdivided into social and environmental issues.

The planning strategy proposed in this volume is part of a trend to search for new and more efficient approaches in order find answers and solutions to the phenomenon of the landscapes of eco-poverty. It proposes a planning approach that is also a hybrid between environmental and social concerns, a new category which may be labeled as 'eco-social'.

Fig. 10 Plant cultivation in the new nursery following the first developments of the Oasis Ecosystem project. (Photo: J. Nakhulo).

Fig. 11 Work on the construction of the new water system form the palmeraie following the first developments of the Oasis Ecosystem project. (Photo: J. Nakhulo).

Endnotes

[1] Barbier, E. B. 2011, *Scarcity and Frontiers. How Economies Have Developed Through Natural Resource Exploitation*, Cambridge University Press, New York.

[2] Millennium Ecosystem Assessment, 2005, *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

[3] Kates, R.W., Haarmann, V. 1992, *Where the Poor Live: Are the Assumptions Correct?*, «Environment», Vol. 34, n. 4, pp. 4-11; 25-28.

[4] Barbier E. B. 2011, op. cit.

[5] This meaning obviously derives from a theoretical stance according to which economic development has a set of established rules that consider the environment and its resources as natural assets whose exploitation is theoretically possible until the depletion of the said assets, thus not considering the effects induced on the earths' ecosystem, while poverty, being a manifestation of the economic level of individuals, can be resolved within the economic system itself.

[6] Coward E. W., Oliver M., Conroy M. 1999, *Building Natural Assets - Rethinking the Centers' Natural Resources Agenda and Its Links to Poverty Alleviation*, proceedings «Meeting on AsESSsing the Impact of Agricultural Research on Poverty Alleviation».

[7] Agudelo C., Rivera B., Tapasco J., Estrada R., 2003, *Designing policies to reduce rural poverty and environmental degradation in a hillside zone of the Colombian Andes, «*World Development», Vol. 31, n. 11, pp. 1921-1931.

[8] Agarwal A., Narain S. 2000, *Redressing Ecological Poverty Through Participatory Democracy: Case Studies from India*, Political economy research institute - working paper, University of Massachusetts Amherst.

[9] Nofroni L. 2017, *Paesaggi delle eco-poverty nel Mediterraneo. Il paesaggio come strumento di osservazione e di proiezione strategica per il superamento delle iniquità eco-sociali.* Tesi di Dottorato in Progettazione e Gestione del Paesaggio e dell'Ambiente Università di Roma La Sapienza, not published.

[10] By 'environmental deterioration' is understood the excess of consumption of biotic and abiotic resources in relation to the capacity the environment has to produce them.

[11] Defined as a process placed along the integration/exclusion axis (Ranci, 1996), it concerns that section of society which, although part of a community is alienated and discriminated upon, excluded both from decision-making procesess and from the use of resources, as well as from those guarantees offered to most individuals or groups belonging to the system (Gallino, 1993), and is based on political, cultural, economic or environmental conditions.

[12] There are many theories concerning social ecological systems. It is worth mentioning the definition established by Redman, Grove, and Kuby, for whom a social ecological system is a coherent system of bio-physical and social factors that interact regularly throughout time; a system that is defined at various spatial, temporal and organisational scales, and which can be structured hierarchically; a system that posesses a set of critical resources (natural, socio-economic and cultural), whose range and use is regulated by a combination of ecological and social factors; a complex and dynamic system in perpetual flux and adaptation. (Redman, Grove, Kuby, 2004)

[13] Most of the active population works in the agricultural sector and has a income that is slightly above 100 US Dollars per month.

[14] Regarding harvests of the previous year, the average production dropped by 32% in the irrigated areas and up to 79% in non-irrigated areas; the losses in the harvests of wheat and barley were somewhere between 47 and 67%; the harvest of wheat produced approximately 2.1 million tonnes (the national food requirements are calculated for that same period at approximately 3.8 million tonnes), thus registering a reduction of almost half of the average long-term production which was equal to 4.7 million tonnes.

[15] The behaviour of the regime in this situation has been widely studied, and it has been highlighted how the economic strategies of the regime may be explained as an attempt to open the Syrian economic system to the world market through a progressive transition from a planned economy to a social market economy, a failed attempt both in terms of means and of manners: the measures of deregulation imposed since 1986 have caused the gradual elimination of some subsidies and other forms of support for agricultural enterprises. The cut in subsidies, linked to the need to reduce the deficit in public finances, was not accompanied by the necessary social welfare measures, and therefore the lack of social security cushions made the cuts to subsidies unsustainable and accelerated the procesESS which favoured social fragility.

[16] Worth R. F. 2010, *Earth Is Parched Where Syrian Farms Thrived*, «New York Times», October, 13rd.

[17] De Châtel F. 2014, *The role of drought and climate change in the Syrian uprising: Untangling the triggers of the revolution*, «Middle Eastern Studies», v. 50, n. 4, pp. 521-535.

[18] The two components can in turn be de-composed into subsystems characterised according to the functions they perform within the system. Four subsystems can be identified, two related to the social component: an economic and government subsystem, and a cultural, technological and values subsystem; and two related to the environmental component: a subsystem related to the factors of reproduction of resources, and a subsystem regarding the control and regulation of the environment.

[19] The system of interaction between pressure factures is organised according to a four by three matrix. In particular, each pressure factor interacts with the others through three interaction processes, due to which it is possible to have twelve correlations (four pressure factors by three interactions). Since the interactions are one-to-one and symmetrical, the process of interaction between the pressure factor PF1 and the pressure factor PF2 corresponds to the process of interaction between PF2 and PF1, and the same applies to the other cases of interaction.

[20] For this reason in the synoptic chart the numbered acronyms are instrumental to its interpretation but do not determine an order or degree of prevalence.

[21] For example, a positive feedback that increases social fragility may be generated by the failure of governmental policies or by the intervention of negative economic choices, whose impact is increased by the interaction with critical social conditions derived, for example, from demographic pressure or the levels of consumption in the population. Thus a positive feedback that increases environmental fragility can be generated by a climatic condition that challenges the control and regulation system and puts pressure on the factors related to the reproduction of resources.

[22] Werrell C. E., Femia F. (2013), *The Arab Spring and climate change: a climate and security correlations series*, The Center for American Progress, Stimson, and The Center for Climate and Security.

[23] Radhouane L (2013), *Climate change impacts on North African countries and on some Tunisian economic sectors*, «Journal of Agriculture and Environment for International Development», no.107, pp. 101-113.

[24] This will result in landscapes that are strongly connotated by a social organisation in which various groups fight for the resources, with areas of the territory in which resources will always be less available and where the poorest sectors of society will be located. In these cases the term environmental justice is used, that is a form of discrimination or social exclusion in which a critical environmental condition – scarcity of resources, pollution, reduction of rights over common assets – underlies and is the direct cause of social criticalities.

[25] This process expresses the interaction between the pressure factors linked to the subsystem of government and to those linked to the subsystem of control and regulation of the environment.

[26]The general disregard from the Syrian regime when the first signs of collapse of the system appeared, in addition to the refusal to use international and national funds and investments for solving the problems related to drought, surely played a relevant role in increasing the damages caused by the drought.

[27] With the term distributive ecological conflict, Martinez Alier indicates the process of social dispute which originates in environmental conflicts of interest concerning the distribution and use of resources and the distribution of the negative effects on the environment of human activities (Martinez Alier, 2014)

Oasis Ecosystem Project: from the desert effect to the oasis effect

Aerial view of the Oasis from the aircraft. (Photo: L. Vallerini).

Lorenzo Vallerini

The idea for the 'Oasis Ecosystem' originated by chance, as is often the case, due to a coincidence of situations and meetings between different people with a common background of interests and passions.

A brief interview given by the author of this chapter to Katie Machell, the Information Officer of the MA Mission Aviation Fellowship, the airline which carried us in its small Cessna airplanes from Nairobi to Loiyangalani and Marsabit during our missions, summarises quite efficiently the causal nature of this experience of research, work and humanity:

> We were trekking in the Suguta Valley toward Lake Logipi[1] about ten years ago, but I got very bad blisters so I had to stop while the rest of the group went on,' he recalls. 'I was taken to Loiyangalani, where I met a group of French people working on an environmental project. They showed me a tree nursery they had planted with the help of a Community Based Organization local group, but it was very badly planned. I could see that the whole eco-system needed to be retrained.' Realising that this was something he could meaningfully contribute to, on his return to work in Florence Lorenzo gathered a team of experts from amongst his university colleagues, and they set about doing a feasibility study. The diverse group of surveyors, chemists, geologists and soil scientists worked together to create a programme focussed on improving water and 'recapturing' the oasis. Their initial study involved a lot of research, including collecting data on the soil, water and vegetation in the area, and carrying out detailed aerial and geological surveys; and it was successful enough to secure them funding from the European Union, and they were able to begin implementing the project.[2]

In 2006, the year in which the idea for the project was born, the Monaco-based association *Wings for Earth* (WFE)[3] had begun a five-year project for fighting desertification called *Nanyori Green Belt* for the protection of the resources and eco-systems and for socio-economic self-sufficiency, directly involving institutions and associations, and beginning an incisive action to spread awareness among the local populations.

The project had triggered several initiatives, among which a Nursery for growing the necessary plants for carrying out a series of interventions and the planting of many trees in the area of the oasis. The interventions, however, were limited to sporadic and isolated plantations, without an effective containment or redirecting of shepherding practices, and a total lack of understanding of the necessary actions for bettering the soil and preparing it for large-scale and coordinated plantations.

This presented a great limit to the possibility of any concrete results for the *Nanyori Green Belt* programme, yet the involvement of the local populations in the undertaking and management of these first initiatives, including the establishment of the local CBO, the *Nanyori Group,* which continued its work even after WFE left the programme Loiyangalani, running the Nursery (production and distribution of plants to the local populations) and involving active individuals in awareness and on field activities, proved to be invaluable.

The *Oasis Ecosystem* project entered this ongoing process, yet redirecting it both from the technical and scientific points of view, with the contribution of researchers and experts, and in economic terms through the allocation of specific funds after the drafting of the project itself, and with an ambitious objective, that of reconstructing the habitat of the Oasis and triggering an *Oasis Effect* with the establishment of a sustainable virtuous circle aimed at inverting the *Desert Effect* by the re-creation of micro-habitats (the Oasis) which oppose the ongoing desertification process and faces the three main problems related to desertification, that is Water, Soil and Vegetation and using, wherever possible, local traditional knowledge (*Promotion of Traditional Knowledge - The United Nations to Combat Desertification*, 2005).

The project of conservation and reconstruction of the Oasis Ecosystem of Loiyangalani has four output areas namely:

- Conservation and reconstruction of the ecosystem resources as a key factor in order to combat desertification;

Fig. 1 The team at Loiyangalani. (Photo: K. Machell).

Fig. 2 Aerial photograph of the oasis. (Photo: L. Vallerini).

- Increase water resources available for both potable and irrigation purposes;
- Realization of prototypes of 'new vegetation' finalized to widen the oasis ecosystem, to increase food productivity for the local populations and to supply new areas of pasture for domestic animals, the increasing numbers of which is one of the main causes for the loss of soil;
- To be involved and to instruct the local populations concerning the realization and management of water resources, the area prototypes and other areas for new vegetation and to improve the socio-economic well-being of the local communities.

The Oasis Ecosystem project is characterised by the work methodology applied. It begins from an 'on-site' research developed on a scientific basis; local traditional knowledge is used when possible, but also 'simple' and 'renewable' innovative technologies for solving problems and ensuring the autonomy of the local populations in view of the future management of the ecosystem. Activities concerning research and the monitoring of results in such an extreme environment represent an 'open-air laboratory' for experimenting with solutions that may be subsequently applied in other areas of the two counties of Turkana, and perhaps even in Mediterranean regions where desertification is a rapidly expanding phenomenon.

The first stages of the project focused on research and on a *Feasibility Project*[4] which was drafted between 2008 and 2010 and co-funded by the Water Right Foundation and the University of Florence, with the support of the *Turkana Scientific Research Group*[5].

Yet only in 2013 was it possible to carry out the ideas proposed in the *Feasibility Project*.

The project was funded by the European Union in 2014 with a total of € 503,344.00 as a part of the *Community Action for Improved Drought Response and Resilience – CAIDRR (SHARE – KENYA)* programme (co-funding of activities with a total cost of € 2,055,166.00) in partnership with the NGO *Veterinarians without Borders, Germany* VSF-G (leading partner), the NGO *Community Initiative Facilitation & Assistance* CIFA-Kenya, and the NGO *Water Right Foundation* WRF-Italy. The drafting of the executive projects and work began on January 1, 2015, and concluded on February 28, 2018, with the 'Hand Over' ceremony, which took place in Loiyangalani, and which included the handing over of the areas and projects carried out to the local institutions and communities.

As mentioned earlier, the proposals were based on a work methodology strengthened by a scientific approach to the problems in the area through inter-disciplinary surveys and research (see the chapters in this book in the section 'Studies and Research') with the purpose of obtaining lasting results and of involving the local population in the future management and development while rooting them to their land and their culture.

Despite the presence of thermal springs, the area of the oasis of Loiyangalani is arid, with sterile soils, very hot and affected by strong winds, with a large mass of water, that of lake Turkana, which is apparently available, yet in fact is not adequate for drinking or irrigation purposes due to its high alkaline levels.

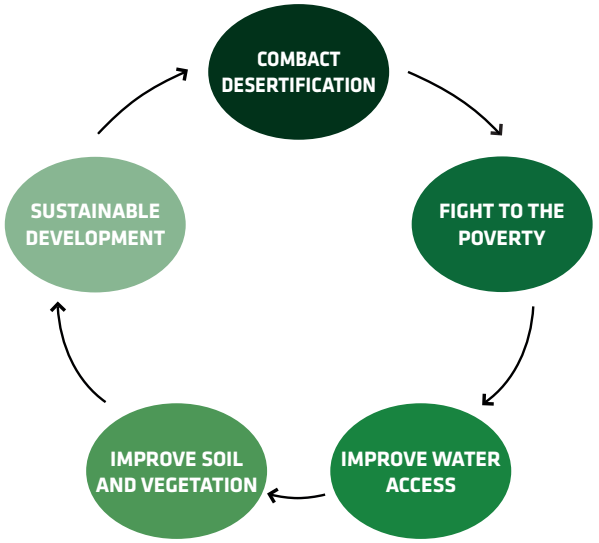


Fig. 3 The circle Oasis Effect-Desert Effect. To face the three main problems related to the desertification: Water, Soil and Vegetation, using local traditional knowledge (UNCD, 2005).

Fig. 4 Doum plams and the Oasis vegetation. (Photo: L. Vallerini).

Fig. 5 Springs in the Oasis. (Photo: L. Vallerini).

The area of Loiyangalani has an average rainfall under 200 mm per annum (North Horr Weather Station). The rainy season usually begins in March-April and lasts until the end of May, the dry season begins in October-November and lasts until the end of December. During the hottest season evaporation is very high and surpasses the total amount of annual rainfall. Average temperature is in the area of 27-29°C with minimum temperatures of approximately 13-20°C and maximum temperatures which reach 26-36°C; the coolest months of the year are July and August, while February, March, and October are the hottest. The winds, as mentioned earlier, are very strong and generated by a low level jet known as the 'Turkana Channel Jet'. This strong current blows all year long from the South East through the East African Rift and the Ethiopian plateaus, sweeping the area from the ocean to the deserts in nearby Sudan. The wind then accelerates at the local level in the areas between mount Kulal (2300 m) and mount Nyiru (2750 m) but due to the drastic change in temperature (cold waters of the lake and hot land), it blows less violently during the day and with full force with powerful gusts during the night.

The morphology of the area is essentially flat with undulating terrain with slight and very slight inclinations, 'difficult' soils and a system of superficial waters that is very poor and would not allow the survival of the local population if it were not supported by the numerous springs, which represent the true source of potable water in the area. One of the main factors of degradation derives from the high degree of erosion of the soil due to natural factors, especially in the more barren areas, rendered even more critical by human activities related to shepherding (goats, sheep and camels, as well as a good number of donkeys) and to the felling of vegetation for providing fodder for livestock, for building materials and fuel. As a result of the population density in Loiyangalani there is also some degree of pollution and some open-air rubbish dumps.

In view of this situation, answers which are not holistic in nature, but rather limited to solve only certain specific issues, are destined to failure. For example, when new wells were made, or systems for drawing water from the springs, without thinking about safeguarding the existing water resources and avoiding wastage, or when 'alien' plants were introduced (such as *Prosopis juliflora* or 'mesquite') which became invasive in the oasis, accelerating the process of the loss of biological diversity in the palm grove[6], or else when new spe-

Fig. 6 A great Acacia tree inside the village. (Photo: L. Vallerini).
Fig. 7 Date Palms in the Oasis. (Photo: L. Vallerini).
Fig. 8 Acacia and Salvadora marriage. (Photo: L. Vallerini).

cies were planted without involving the local populations (for example the case of the date palm groves in the area of Turkwell, to the north-west of Turkana), etc.

Other projects, however, carried out in other arid zones using more scientific criteria and approaches, and paying careful attention to the existing social and environmental situations, have obtained more positive results.

The 'Great Green Wall' of the Sahara and the Sahel Initiative (GGWSSI 2005)[7] is a project to plant a wall of trees across Africa at the southern edge of the Sahara desert as a means to prevent desertification. It was developed by the *African Union* to address the detrimental social, economic and environmental impacts of land degradation and desertification; it is not only a reforestation initiative, it is a programming tool for rural development and to improve food security.

The first green wall project, twenty years ago, envisaged the planting of one million alien trees such as eucalyptus and was rejected. Today in Niger, Chad, Burkina Faso, Mali, Senegal, etc., only autochthonous plants are used[8], in agreement with local farmers and populations, which enrich the soil with nitrogen, produce leaves that are rich in protein and other marketable products, protect from the wind and sand, and help the water penetrate the soil. In Senegal, additionally, the reforestation carried out with plants grown in nurseries run by locals permitted not only to begin livestock farming again, but also the development of a flourishing local agriculture, to such an extent that jobs were created and immigrants returned to their homeland.

In Egypt, Ibrahim Abouleish, an engineer and entrepreneur who won the Alternative Nobel Prize[9] in 2003, had worked since the Seventies to transform, with the help of his wife Gudrun, 1,500 hectares of sand in the desert into a biodynamic farm which now exports to many countries and provides jobs for hundreds of people[10].

In the Ketura Kibbutz in Israel, located in Arava, the most arid and parched region of the country, ways are sought for facing climate change and producing enough food for people who have been fighting since antiquity against the scarcity of water and developing agricultural methods in extreme conditions. In the Arava Institute for Environmental Studies in Ketura, among the traditional crops tested which have proven to be successful while needing little water, the most promising seems to be an ancient variety of the date palm[11].

The cornerstone of the whole process, the objective toward which to

Fig. 9 New plantings of Neem tree with protection against goats. (Photo: L. Vallerini).
Fig. 10 The old Nursery. (Photo: L. Vallerini).
Fig. 11 El Molo village. (Photo: L. Vallerini).

proceed, seems to be precisely agriculture, yet not an industrialised agriculture separated from its social and environmental context, but rather integrated to it and interconnected to other strategies for expanding the natural and autochthonous vegetation and for safeguarding and enhancing the fertility of the soil.

Fritjof Capra, a physicist and systems theoretician who has been interested for many years in the great topics related to sustainable development, affirms that through

> agro-ecology [...] which refers both to the scientific foundation and the practice of an agriculture based on ecological principles [...] a set of environmental principles which were refined during the 20th century and adopted throughout the world, especially over the past twenty years [...] it is possible to cultivate the land in a sustainable and decentralised manner, in full respect of biodiversity, of the communities involved and of energy efficiency.

And he adds that

> Farmers who cultivate the land following the principles of agro-ecology recur to techniques based on the knowledge of natural systems for increasing the harvest [...] and enhancing the fertility of the soil [...] diversifying agricultural systems, which results in a mix of crops by consociation (cultivation of two or more varieties in proximity of each other), agroforestry (combination of trees and shrubs with crops) [...] integrate livestock in such a way as to support surface and soil ecosystems. Agroecological practices require intensive labour, thus fostering the reduction of poverty and social exclusion and operate in favour of the community [...] diversified agricultural systems are capable of adapting to the consequences of serious cases of drought, ensuring a greater harvest stability.[12]

The use of traditional agricultural techniques and their integration to tree and shrub vegetation systems thus not only seems to be the true and ultimate answer to both a greater food security and the survival of millions of people who live in arid regions throughout the world, but also the only viable alternative for efficiently opposing the expansion of the desert.

We have attempted to do this in Loiyangalani, within the limited spatio-temporal frame available to us, yet the road to environmental, cultural and social change is long and we are only at the beginning. In our case mostly to transform a nomadic culture into a sedentary farming-oriented culture, in other parts of the world, especially in industrialised societies, to transform a culture of waste into one of coexistence with our limited ecosystems.

Fig. 12 Fisherman at the Lake. (Photo: L. Vallerini).

Endnotes

[1] Lake Logipi is saline and lies at the northern end of the Suguta Valley, south of Lake Turkana, separated from it by the barrier volcanic complex. It is between three and five metres deep, and is 6Km wide and 3Km long. Flamingos inhabit the saline waters.

[2] Machell, K. 2016, *Comments on story,* Information Officer, Mission Aviation Fellowship-MAF - Nairobi, Kenya, 27th of June 2016, in 'Flying for Life' The quarterly magazine of MAF.

[3] The Association *WFE- Des Ailes pour la Terre / Wings for Earth* with headquarters in Monaco-Montecarlo, has carried out activities in Kenya since 1999. It is an apolitical and no confessional environmental NGO which works in support of harmony between people and their environments. At present it carries out activities in Kenya in the area of Amboseli.

[4] AA.VV., 2008-2010, *Feasibility Project 'Conservation and Reconstruction of the Oasis Ecosystem of Loiyangalani- Scientific Report',* Florence, Italy, unpublished (Funding: WRF, 2008-2009 € 25.000,00 – University of Florence, University Scientific Research Project (ex quota 60%) Operative manager: Lorenzo Vallerini, 2007,2008,2009 € 9.000,00 - Acquifera Onlus, Geophysical Survey, 2011 € 5.000,00). Ceccanti G., Vallerini L., 2011: *Oasis of Loiyangalani Kenya – Combat Desertification – Water Resource Management*, «AQUA mundi – Journal of water sciences», Vo. 02, no. 01.

[5] *Turkana Scientific Research Group- Florence, Italy*: Lorenzo Vallerini, DIDA University of Florence. Head of the Project and Scientific Coordinator: Giovanni Caponi; Surveyor, Surveys and Cartography: Marco Folini and Giancarlo Ceccanti Acquifera Onlus, Geologists; Underground Water: Marco Mazzoni and Paolo Altemura, Chemists; Quality of Water: Piero Magazzini and Ugo Wolf, Soil Scientists.

[6] http://keys.lucidcentral.org/keys/v3/eafrinet/fs_images/fs_title.gif "*Prosopis juliflora* is invasive in parts of Kenya and Tanzania (Global Invasive Species Database) and in northern Uganda (A.B.R. Witt pers. obs.). In Kenya this species was originally introduced in the arid and semi-arid areas of Kenya such as Baringo. It has recently dramatically expanded its range and is now widespread in Kenya […]. Prosopis juliflora has been declared a noxious weed in Kenya in 2008 under the Suppression of Noxious Weeds Act (CAP 325). Under this act the Minister of Agriculture, can compel land owners who have such declared noxious weeds growing on their land to remove or have it otherwise removed." Editors: Agnes Lusweti, National Museums of Kenya; Emily Wabuyele, National Museums of Kenya, Paul Ssegawa, Makerere University; John Mauremootoo, BioNET-INTERNATIONAL Secretariat – UK.

[7] http://www.greatgreenwall.org/great-green-wall/, 22 October 2017. Fraschetti V., 2015, *Una foresta nel deserto*, «D La Repubblica», June, 27th.

Saragosa A., 2016, *Se il muro è verde non divide ma protegge*, «Il Venerdì La Repubblica», January, 8th.

[8] *Faidherbia albida* in Niger, *Acacia senegal* and *Balanites aegyptica* in Senegal, etc.

[9] The *Alternative Nobel Prize or Right Livelihood Award* is an annual award created in 1980. The purpose of this award is to be presented in juxtaposition to the traditional Nobel Prize in order to recognise the efforts carried out by individuals and groups, especially from underdeveloped countries, for a better society and a fairer economic system.

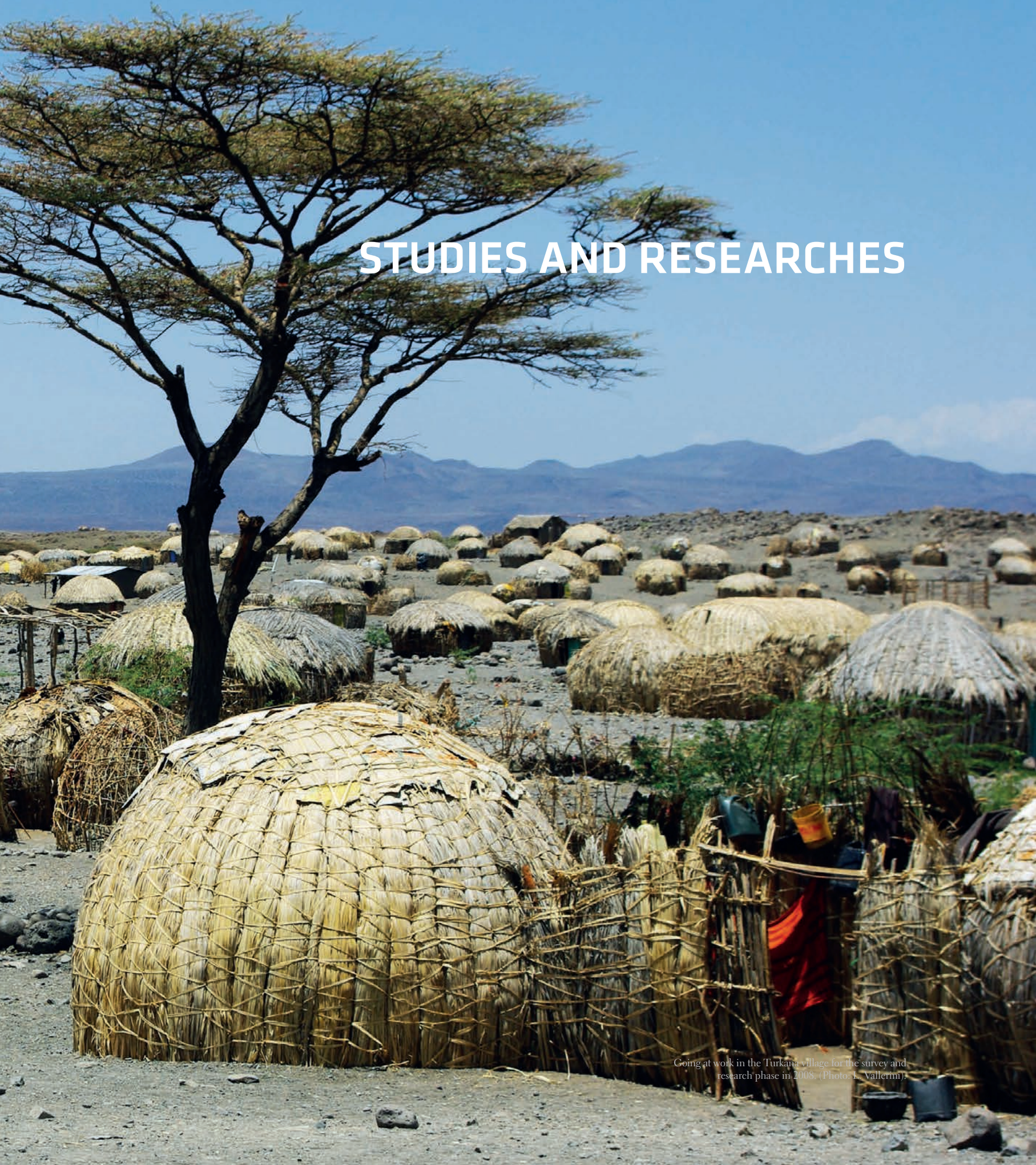
[10] http://www.sekem.com/en/index/, 22 October 2017. Cianciullo A, 2015, *L'uomo che trasforma il deserto in giardino*, «La Repubblica», February, 21st

[11] http://arava.org/academics/campus-life/life-on-the-kibbutz/ 22nd October 2017.

Frattini D., 2015, *Fermiamo vento e sabbia con il DNA di Matusalemme*, «Corriere della Sera», September 1st.

[12] Capra F., Lappè A., 2016, *Agricoltura e cambiamento climatico*, Aboca S.p.A., Graficonsul Srl Sansepolcro (AR).

STUDIES AND RESEARCHES



Going at work in the Turkana village for the survey and research phase in 2008. (Photo: L. Vallerini).

Surveys of the Oasis: aerial photography, planimetric and altimetric surveys and digital cartographic restitution

Photomosaic of the Oasis of Loiyangalani, Aerial Photo Survey by the Turkana Scientific Research Group, 2nd of September 2008, Scale abt 1:3.500.

Giovanni Caponi

The surveys covered the entire area of the Oasis at the territorial scale during the feasibility study phase, while during the execution phase of the projects they focused on the five areas of intervention with the design specifications necessary for the working drawings and the on-site execution.
All survey phases were preparatory for the studies, research and projects undertaken.

Survey of the intervention area at the territorial scale

The area is represented in Kenyan official cartography maps at a 1:100.000 scale (Kulal) and at a 1:250.000 scale (South Horr). However, the typology of the existing cartography, due to the scales of representation, was not adequate for in-detail surveys. Those maps were therefore useful only for informal consultations of a general type.

Data obtained from the available cartography

Series Y633 – 1:100.000 – Survey of Kenya

Data	Description
Area of interest	Kulal
Sheet	series Y633 - sheet 41
Scale	1:100.000
Data Source	Survey of Kenya
Compilation date	1960 (first edition)
Air coverage	Jan-Feb 1957
Map Projection	Transverse Mercator
Datum	Spheroid Clarke 1880
Grid	East Africa – belt H

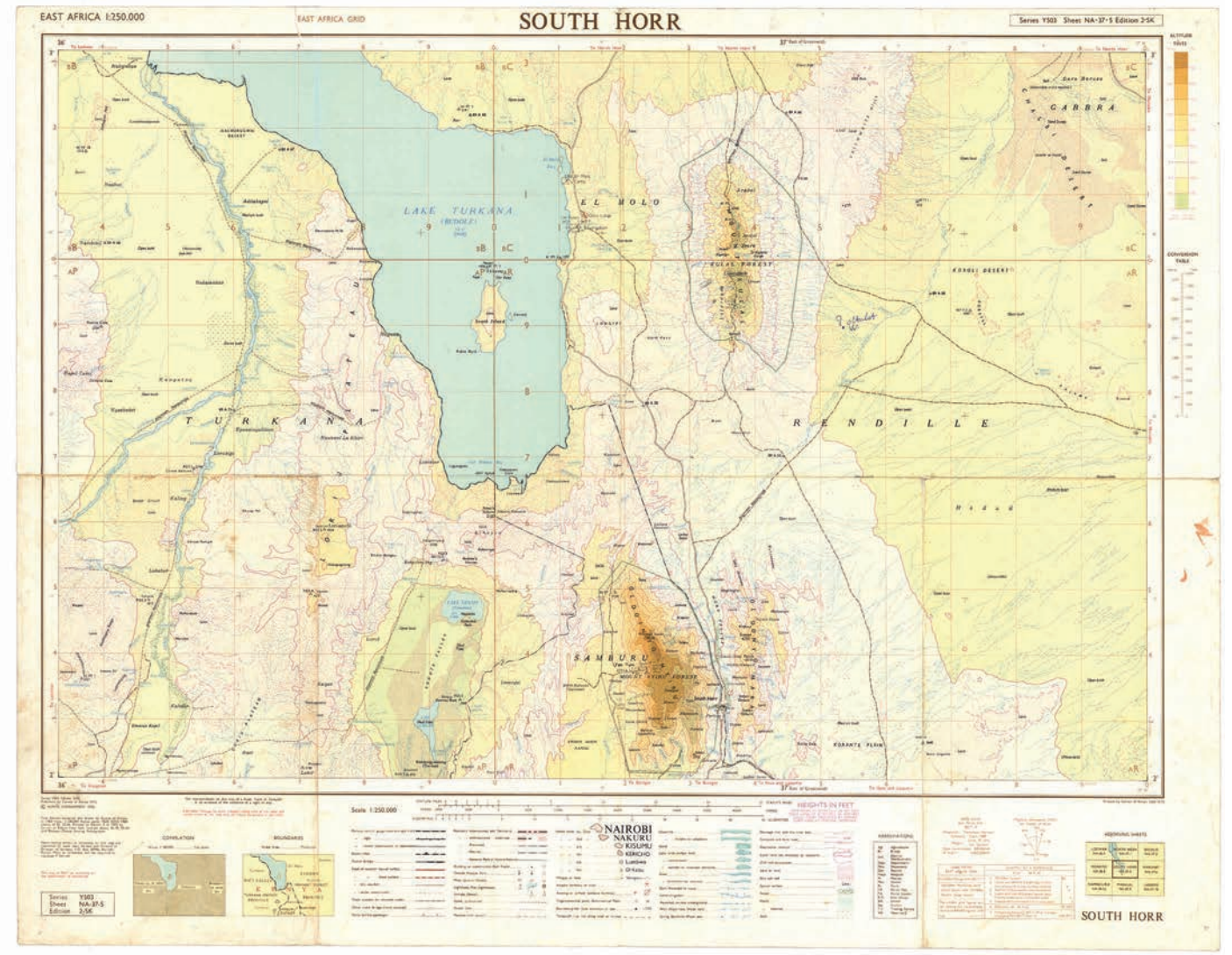
Series Y503 – 1:250.000 – Survey of Kenya

Data	Description
Area of interest	South Horr
Sheet	series Y503 - NA-37-5
Scale	1:250000
Data Source	Survey of Kenya
Compilation date	1963 (first edition) – from 1:100.000
Revised date	1975 (edition two) - field revision
Map Projection	Transverse Mercator
Datum	Spheroid Clarke 1880
Grid	East Africa – belt H

Consequently, with the purpose of carrying out a more detailed survey of the area of the project, we verified the existence of a possible satellite coverage of the zone. This research was undertaken through the companies specialised in the distribution of satellite images. The company of reference for the African continent is MAPS geosystems, through its European branch in Munich, Germany. It was soon evident that the zone was not one of the best covered areas by satellite missions.
It would have been possible to carry out a specific satellite coverage, yet it would have taken a long time and been costly without guaranteeing the certainty of a perfect result in terms of the clearness of the images and of the absence of clouds during the shooting of the photographs. Additionally, the programming of the satellites is determined only in terms of the date of availability, independently of the weather conditions in the area where the operation is requested.

Digital restitution

The SPOT5 image had a local referentiation of WGS84 in the UTM 37 reference system, and the relevant TFW file permitted locating the zone in its actual geographic position, with the subsequent insertion of the DEM (Digital Elevation Model), with 10 metres equidistant contour lines, obtained from the University of Nairobi.
The use of the SPOT5 image allowed covering the following basic themes: primary road systems, hydrography, vegetation areas, and masonry buildings.
A cartographic survey on a 1:10.000 and 1:5.000 scale was carried out using a monsocopic method[1], marking all the recognisable ground-level details that represented natural or artificial objects or boundaries present in the territory. These data were acquired and codified according to their specific features. The rules for cartographic representation, regardless of the fact that the scale was 1:10.000, imposed the need for summarising certain types of dwellings in a punctual,



rather than an aerial way. A simplification that was necessary due to the actual dimensions of the details, which did not allow tracing perimeters, in relation to the denominator of the cartographic scale.

Data from the satellite image

Data	Description
Area of interest	KENYA – Loyangalani area
Size	100 km^2
Data Source	SPOT5
Date	2007
Product Type	Enhanced Standard
Imaging Bands	Panchromatic
Bit Depth	8
File Format	TIFF
Map Projection	Transverse Mercator
Datum	WGS84
Grid	UTM 37N

The cartography was therefore assigned the function of a 'reconnaissance draft', to which further data from the subsequent survey phases would be added. That is the data obtained from planimetric and altimetric surveys as well as from a possible aerial survey.
The digital restitution file was obtained through AutocadMap 3D, in DWG format.

Aerial survey

The analysis of the SPOT5 image therefore highlighted a limit to the determination of the details to be acquired in the phase of compiling the restitution. The insufficient definition of the resolution at the ground-level of the image, close to 5m, did not permit a satisfactory survey of the geo-morphological details in the area.

Fig. 1 Map of Lake Turkana South (Source: East Africa, Scale 1:250.000, Sheet South Horr NA-37-5, Survey of Kenya, Kenya Government 1975). (Source: East Africa, Scale 1:250.000, Sheet South Horr NA-37-5, Survey of Kenya, Kenya Government, 1975).

During the various missions in Loiyangalani, in addition to the usual surveys, an aerial coverage was undertaken with the use of a digital reflex camera with the purpose of enhancing the acquisition obtained from the satellite image, especially for surveying in a comprehensive manner the numerous buildings, mostly shacks and huts.
The aerial coverage was carried out only in the inhabited section of Loiyangalani, through a flight plan divided into 5 (five) parallel strip-runs. The available equipment did not allow the programming of the exact intervals for the placement of the adjacent shots, as well as the longitudinal and transverse overlapping between frames.
The aerial coverage was carried out on a CESSNA 206, at an average height of approximately 600 metres.
The digital camera used was a Pentax K20D reflex (focal length approximately 18,0 mm.), which permitted saving the images in JPEG format with an average scale of approximately 1:3.500, subdivided into 56 shot-images.

The strip-runs were carried out as follows:

Strip-runs	Images
1	9
2	12
3	7
4	2
5	16

Digital photomosaic

In addition to the cartography in scales of 1:10.000 and 1:5.000, also the digital photomosaic of the area was prepared. On the basis of the restitution, those images from the aerial coverage considered necessary for the mosaic were cropped, oriented and included.
The photomosaic (JPEG format) permitted obtaining a complete image of the zone and to develop with greater detail the vegetation and soil maps.

Planimeric and altimetric survey

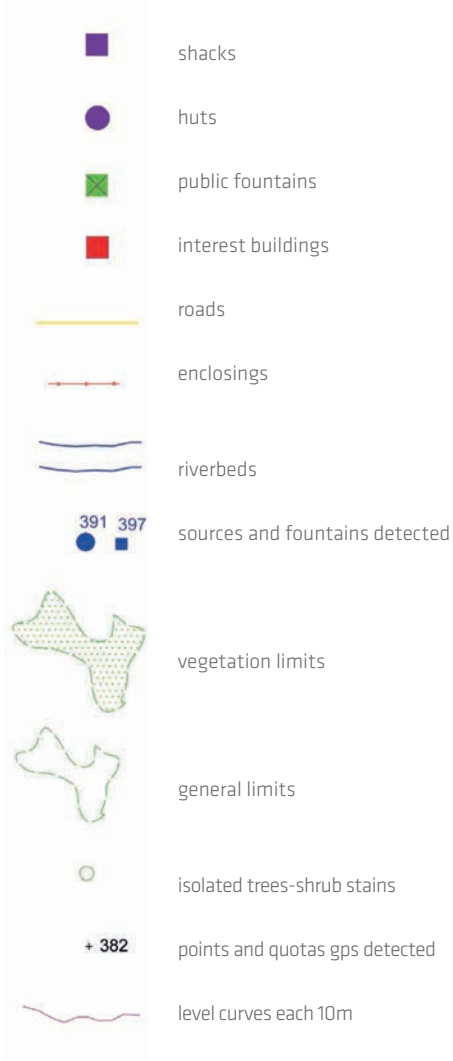
The planimetric and altimetric survey carried out during the various missions undertaken in the area with the support of a GPS receiver were added to the digital restitution.
The tools consisted in a hand-held or PDA Garmin GPSMap 60C receiver, with an acquisition accuracy for the surveyed points of approximately 3 to 5m (in 95% of the cases), in DGPS mode, where D stands for 'differential' procedure. The PDA can acquire the signals of up to twelve satellites. The precision obtained in the establishment of the points was considered in line with the quality of the available material.
The cartographic projection and the reference system used were the WGS84 with UTM 37N, a solution which is envisaged in the various functions of the PDA.
The survey permitted obtaining other elements in detail in support of the digital restitution. On the final cartography these details, obtained on site and provided as integration and control elements, are easily recognisable and are identified with a crosshair and altimetric quota. These are: fences, kerbs, gates, pedestrian walkways, landing strip, etc.
In fact, some geomorphologic and topographic details were the object of an accurate planimetric and altimetric survey. A work system which attempted to highlight certain objects and points that were not easily identifiable either through the SPOT5 image or the aerial survey, yet were necessary for the work group, such as wells, springs, types of vegetation, observation points and types of soil.

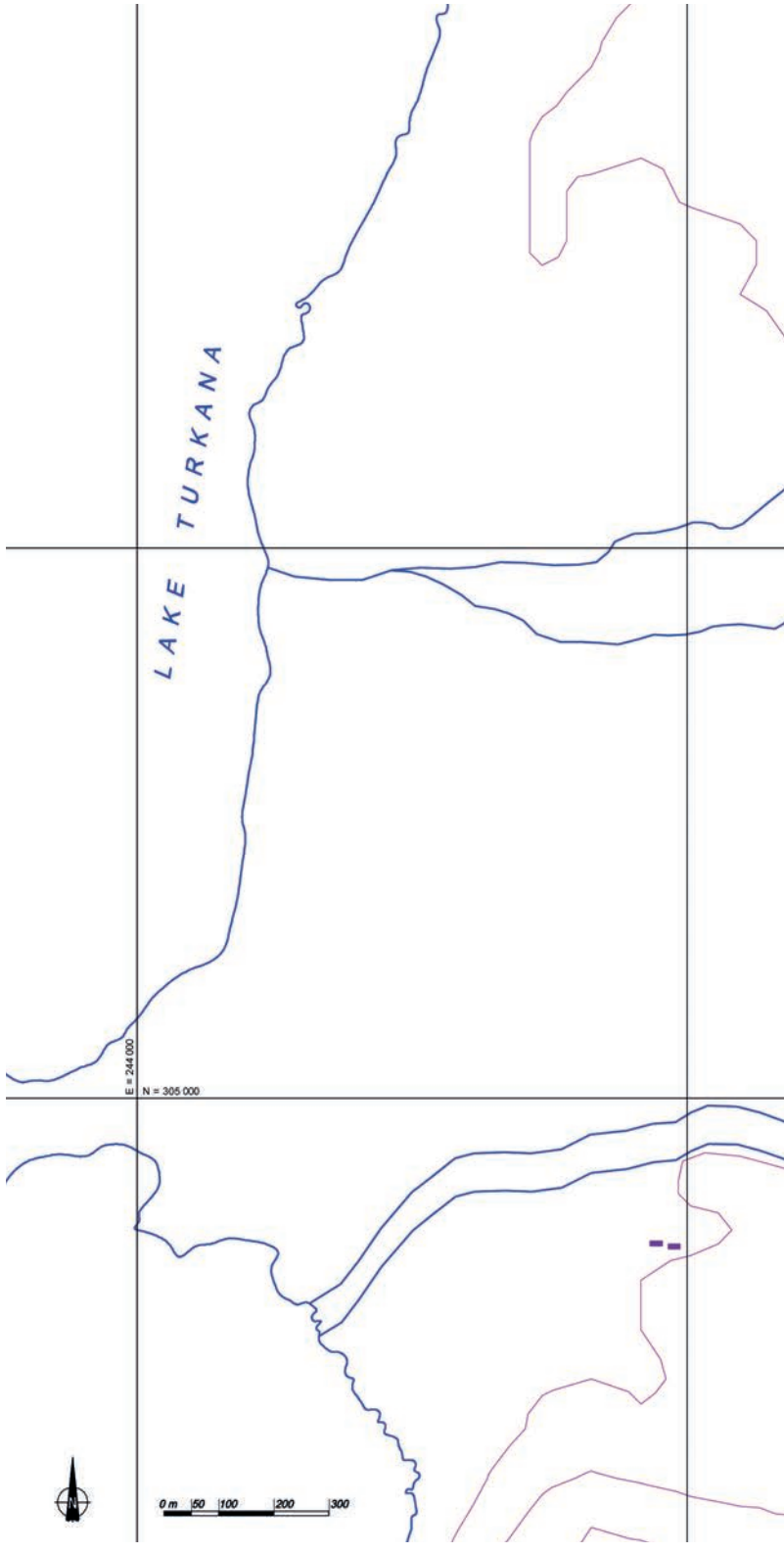
Survey of the area from satellite photographs up to December 2007. Detailed surveys of the intervention areas

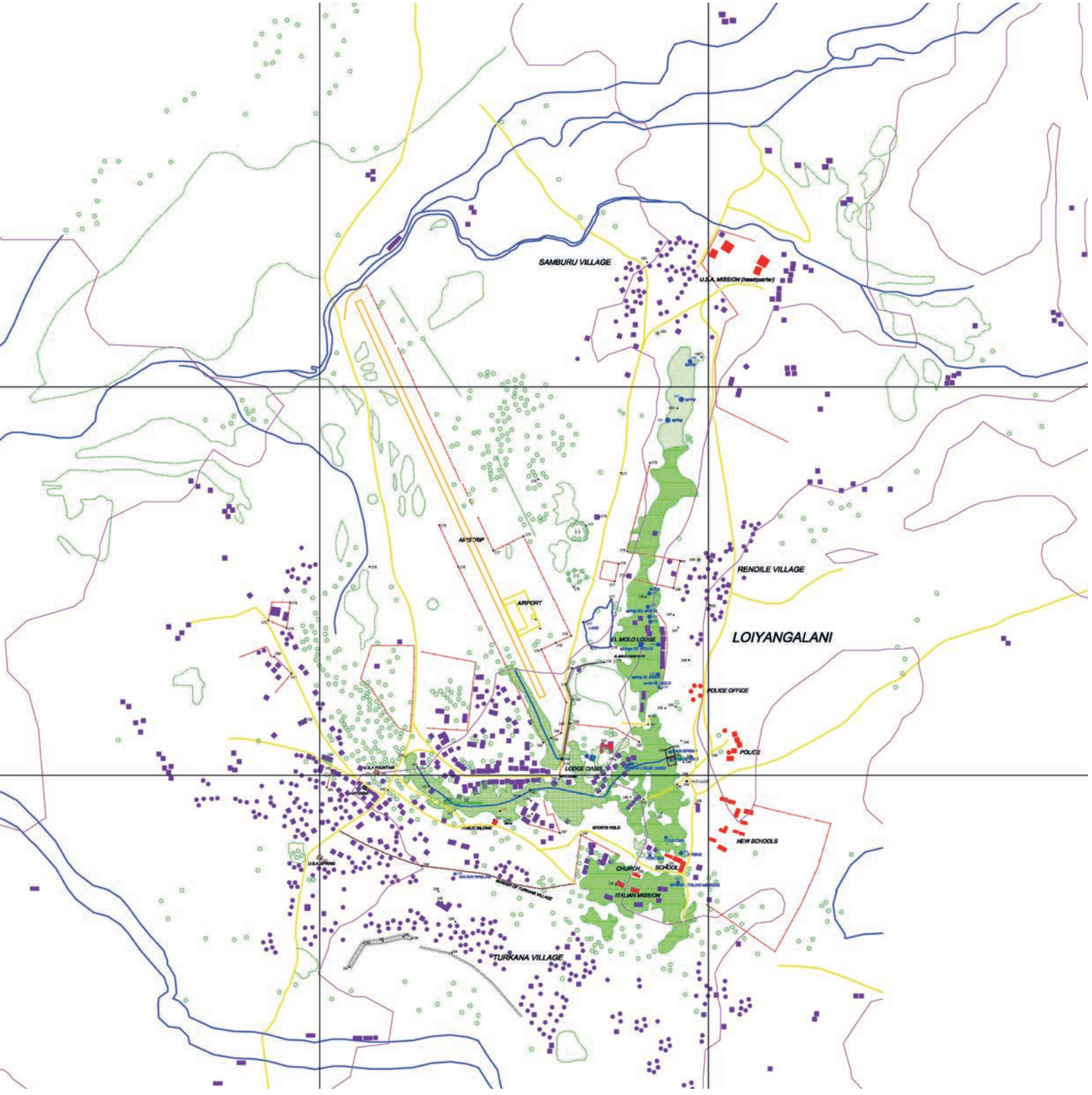
On the occasion of the mission of October 2015, detailed surveys were carried out for the areas involved in the project, definitely identified with the help of the Total Station Leica TCR 705 with a 5'' angular precision, which was considered the most adequate topographical instrument for the environmental and morphological features of the said areas.
Regarding the general planimetric and altimetric framing, the antenna tower of the Kenyan telephone provider Safaricom, which was visible from all the areas involved in the project, was chosen as trigonometric reference point.

Vetiver Area. The planimetric and celerimetric survey of this area, with an estimated extension of approximately 11,500 m2 was carried out without much difficulty (in the end the are was reduced to about 8,500 m2). Two topographical stations were used and approximately 100 survey points were observed for the cartographic restitution. In particular, the bordering zones of the area considered as important for the project were surveyed, including the position of vegetation present in the said area.

Fig. 2 Field Survey – 1:5.000 by the Turkana Scientific Research Group, 2010-15.



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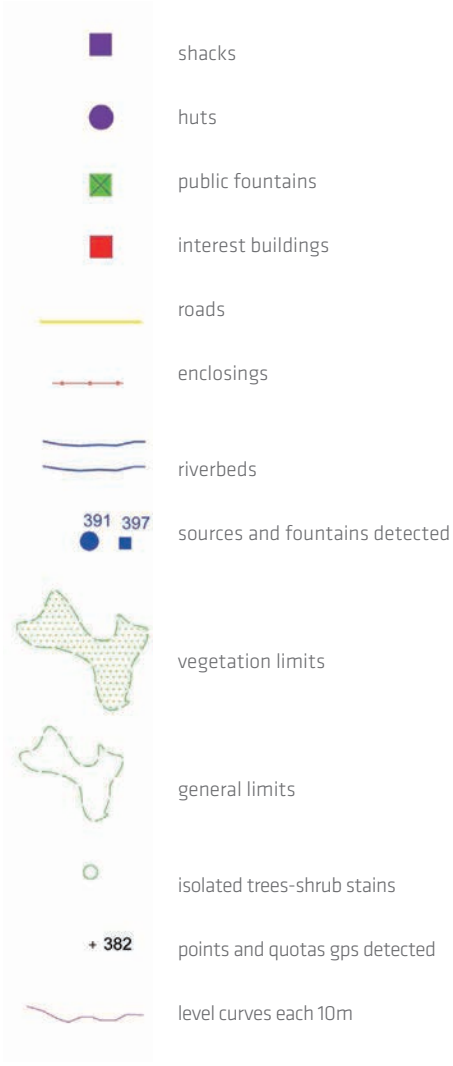
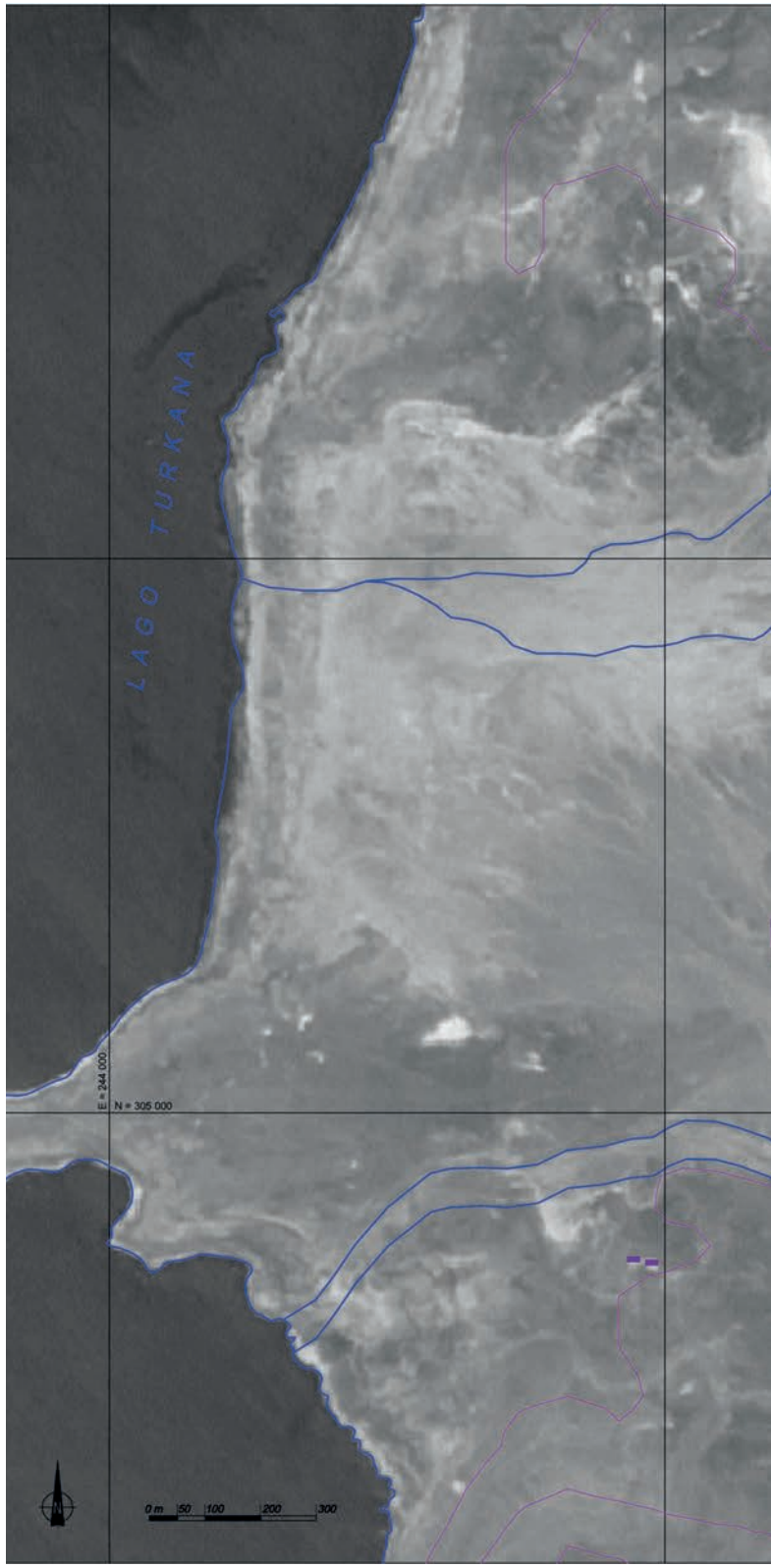
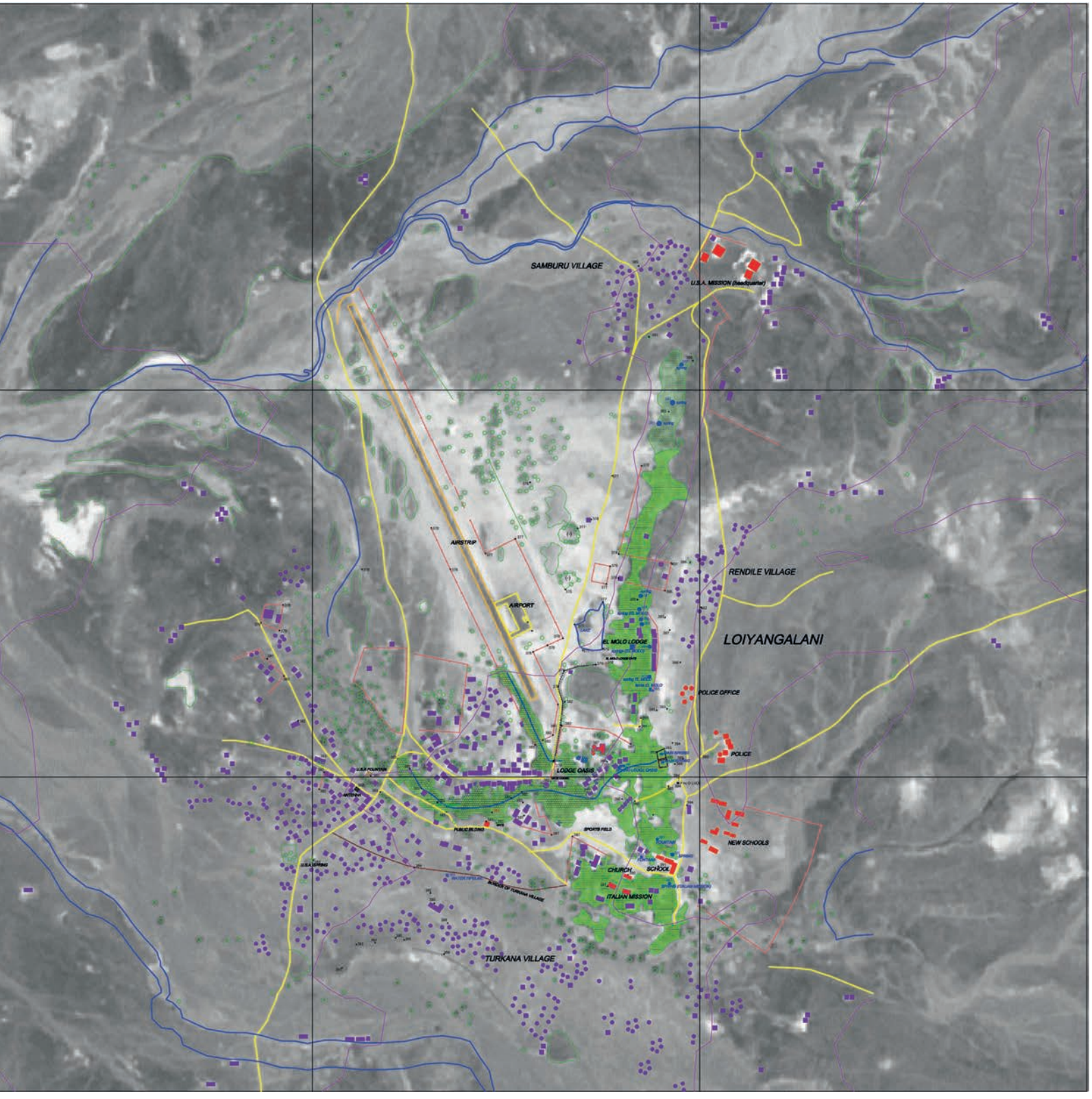
U.S.A FOUNTAIN
SPORTS FIELD
NEW SCHOOLS
CHURCH
SCHOOL
ITALIAN MISSION
TURKANA VILLAGE

Fig. 3 Overlaid Survey and Satellite photo (Maps Geosystem, 2005, Monaco, Germany) 1:5.000 by the Turkana Scientific Research Group, 2010-15.



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SCHOOL
ITALIAN MISSION
TURKANA VILLAGE

Fig. 4 Growth of vegetation in the waters of the Lake Turkana. (Photo: L. Vallerini).

Nanyori Area. The planimetric and altimetric survey of this area, with an estimated extension of approximately 4,500 m2 (in the end the area was reduced to about 850 m2), included the observation of many details such as boundary fences, dwellings and service buildings near the area and in particular the water fountain that services the community, which the project requires for the purposes of the construction of the building and the carrying out of the Compost Plan. Also within the area, already fenced, there were certain details to be surveyed. Three topographical stations were used and approximately 130 survey points were observed for the cartographic restitution.

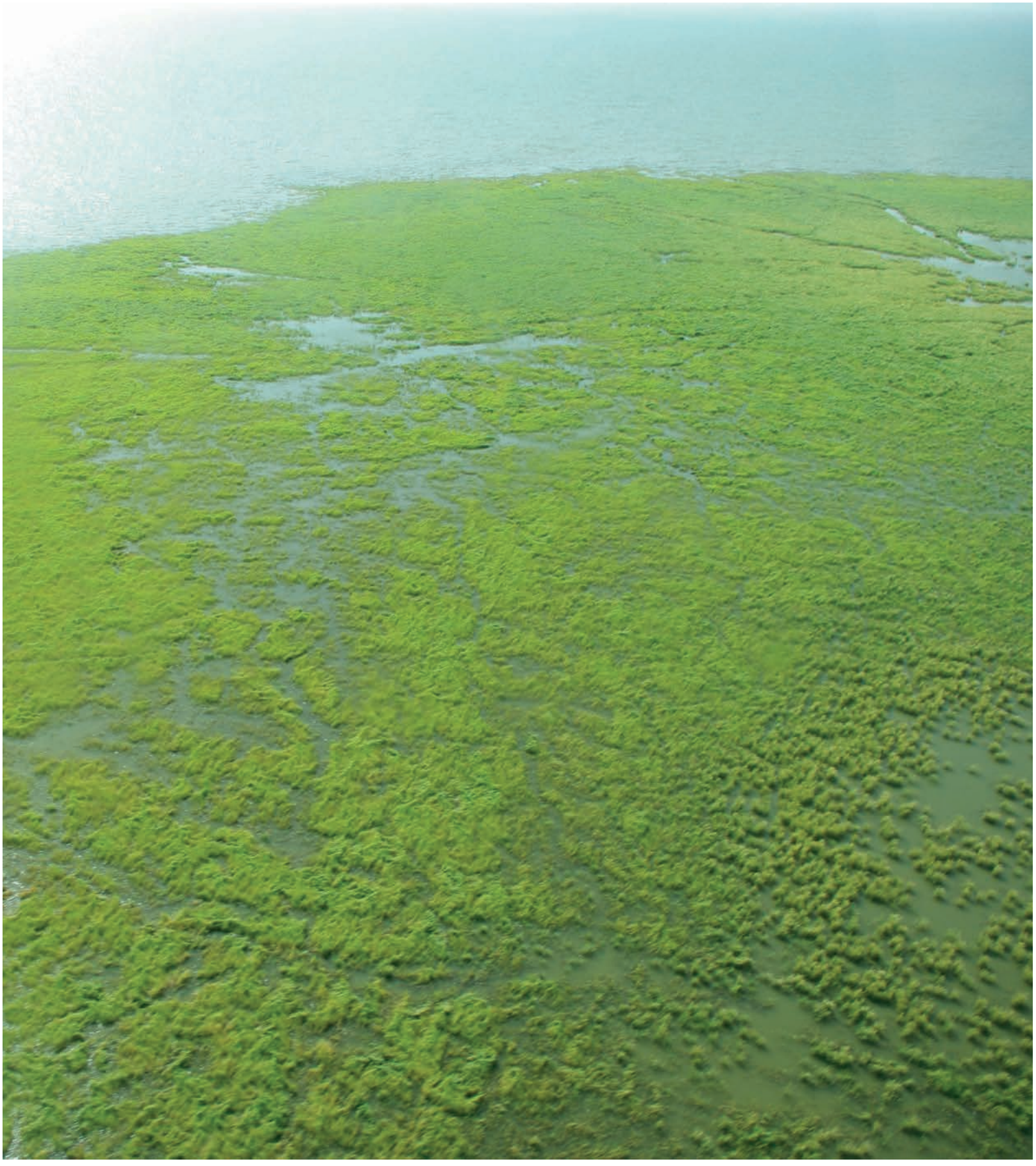
Well Area. The planimetric and altimetric survey of this area, with an estimated extension of approximately 10,000 m2 (in the end the area was reduced to about 4,000 m2) in addition to the existing details, included the need to determine the points for understanding the elevation difference and inclination between the position of the well and that of the water-collection tank. The entire survey was carried out from a single topographic station and with the use of approximately 90 survey points.

Palmerie and Afforestation Areas. The planimetric and altimetric survey of these areas, which are adjacent to each other, with an estimated extension of approximately 15,000 m2 (in the end the area was reduced to about 9,000 m2) proved to be the most complex and difficult, especially due to the dense presence of vegetation and palm-trees. The survey established the exact location of this vegetation both from the existing roads, as well as from the alleged property boundaries, ensuring that the areas had been identified within the said limits. A main topographic station was necessary, from which the other five stations needed for completing the survey were established, for a total of approximately 200 detail points. It is worth mentioning that the exact locations of the springs found in the proximity of the two areas were included in the survey.

The cartographic restitution of all surveys was carried out at a scale of 1:200 with a 0.050m equidistance of the contour lines and for an easier reading it was also superposed to the latest available satellite image from 2007.

Endnotes

[1] The monoscopic or 'swift' method consists in the rectifying of the individual photograms, from which a bi-dimensional orthogonal projection is then derived, parallel to the framed area.



Geological Aspects and Geomorphology

Air view of the craters and the lava landscapes in the southern part of the lake. (Photo: L. Vallerini).

Giancarlo Ceccanti, Marco Folini

The African 'highlands'

Kenya, with the Ethiopian plateau, is part of the so-called African *highlands*: a series of mountainous chains separated by deep depressions generated by the evolution of the Rift Valley, in which fresh or brackish water lakes are often present.

A large section of the Kenyan territory is situated at approximately 2,000 metres above sea-level, yet there are higher points such as Mount Kenya, with an altitude of over 5,000 metres. Most of these mountains were generated by the volcanic activity of important eruptive centres connected to deep fractures in the Rift Valley; other elevated geographical features consist instead of imposing granite blocks brought to the surface during the orogenic phases that determined the landscape in this part of Africa.

Interior depressions of an endorheic type include important lakes, such as Turkana, Baringo and Nakuru, whose waters are strongly influenced by phenomena of deep surfacing of geothermal fluids which greatly condition their chemical composition.

The oriental section of the African Continent is geologically very complex, and has been generated by a succession of deformative events, often characterised by opposed tectonic styles. The main geodynamic episodes which occurred in this area derive from the clash between two lithospheric plates, the mobile belt of Mozambique and the Tanzanian craton[1] and from the opening of the rift system known as the *East African Rift System*.

The Kenyan Rift is located within the eastern branch of this important structure, and near the equator it intersects the margin that separates two lithospheric plates forming a geographical convex wide feature known as the *Kenya Dome*. The extension, intensity, and physical feature of these deformative events have contributed to perturb the layout of the deep structures present in the Kenyan lithosphere, thus creating evident connections between these superficial geodynamic phenomena.

The geology of eastern Kenya therefore derives from the succession of deformative events with diversified tectonic styles: after the clash between plates during the Precambrian period, a great distensive system was developed which crosses the entire eastern area of the continent from north to south, covering an extension of over 3000km. It develops from the oceanic rifts in the Red Sea and the Gulf of Aden and the Afar depression, in the north, to the Zambezi river in the south.

In the area that separates Ethiopia from Kenya (5°N) this imposing structure, known also as the *East African Rift System* (EARS), splits into two secondary distensive systems: the *Western Branch* and the *Eastern Branch,* which delimit the margins of the Tanzanian plate. The western branch crosses the great Central African lakes and is the more recent and less developed of the two extensional systems. The eastern branch crosses Kenya and is at the origin of a continental rift made of two parts, characterised by different stages of evolution: one to the north, the Turkana Rift, which is older and probably influenced by the nearby Ethiopian rift, and one to the south, the Gregory Rift, much younger and within which stands the convex structure of the *Kenya Dome*.

The Kenyan Rift is a tension tectonic structure genetically connected to an astenospheric intrusion whose base probably lies under the Tanzanian craton. The system is active, as can be seen by the existing volcanic, geothermal and seismic activity, which is mostly situated within the Rift.

The geology of lake Turkana

Thanks to the analysis of various strata of volcanic ash it was possible to reconstruct the geology of Lake Turkana as far back as 4,5 million years ago. In that period the basin was covered by a huge freshwater lake with an extension of approximately 28,000km^2, while its extension today is of 7,500km^2.

Between 3 and 2 million years ago, the lake was substituted by a river system which probably flowed toward the east until it reached the Indian Ocean; the Omo river, its only tributary, with its sediments which originated in Ethiopia, filled the basin until it came to occupy

Fig. 1 View of the southern section of the lake with the evident presence of lava flow just below the surface. (Photo: M. Folini).

the entire western side. Today, the high degree of evaporation and the drought that has affected the area over the past few decades are altering the basin's traits, to the extent that in a little less than a century the level of water has dropped 15 metres.

Turkana lake lies within the depression of Turkana, a complex structural basin between the Ethiopian and Kenyan plateaus; to the south basaltic lava from the Miocenic, Pliocenic and Pleistocenic periods frame sedimentary continental deposits which are linked as well to the various phases of lacustrine deposition (lacustrine sediments, fluvial and delta deposits), with a maximum thickness of 325 metres. The pliocenic and pleistocenic deposits lie discontinuously on late Miocene and Pliocene lava rocks and are slightly dipping toward the lake; outcroppings are discontinuous, forming small hills and are often covered by fluvial terraces and aeolian sands.

Within the area analysed and its surroundings, basalt formations from the Quaternary and Miocene periods emerge, which constitute the rocky substratum. They are the result of volcanic activity derived mostly from fractures and small volcanic bodies and they are present in ridges and plateaus with calderas and volcanos, one of which was active until the mid-19th century.

These basalt formations surface almost always under the form of pillow lavas, whose underwater formation may be considered the most common eruptive process for basic composition magma; the *pillows* are formed, in fact, when the lava, still hot and fluid, comes in contact with great amounts of water and solidifies rapidly; the structure results from the protrusion of elongated lobes through cracks in the crust due to the fast cooling down process.

Geological features of the Loiyangalani area

700 kilometres separate Nairobi from Lake Turkana, and the landscape changes radically; from zones in which the vegetation is lush, through increasingly arid savannas, until reaching desert areas. After a few hundred kilometres, the Earth shows its skeleton and presents spectacular geological forms. The entire area which comprises the alkaline lakes of Bogoria, Nakuru, Elmentaita, Naivasha and Magadi, represents a kind of border area where sweltering temperatures, wind and water express all their own force and continuously change the appearance of a territory in which surprising shapes alternate: lava cones and amphitheatres, faults, fractures, corrugations and depressions.

The examined area consists of a rectangle approximately ten kilometres long and three/four kilometres wide that extends in a north-south direction from the bay of El Molo to the Oasis of Loiyangalani, between the Mount Kulal range to the east and the eastern shore of Lake Turkana.

The analysis of satellite images and on-site surveys resulted in the recognition of two different morphological domains in this area: the topographically higher domain, constituted by miocenic basalt plateaus on the eastern side of the rift, and the domain formed by the sedimentary deposits of the lacustrine regression, which cover in a discontinuous manner the various lava flows.

These two different geomorphological structures are broken by faults and fractures which divide the surface in a NW/SE and NE/SW direction, and secondarily in a NNE/SSW direction, and which have dislocated the basalt plateaus, on which the main drainage lines

Fig. 2 Basalt lava front in close contact with the Oasis. (Photo: M. Folini).

were developed; the same system of fractures conditions the contour of the shoreline of the lake that in this section of the shore is very jagged and angular.

From the observation of the satellite immagines it can be seen how the Oasis of Loiyangalani lies between two basalt planes which correspond to different depositional events: the more recent lava front, topographically higher, forms a sort of amphitheatre, a narrow arch that carried out an action of morphological control of the sedimentation of material transported by deflation both from the coast and from rivers. Although only a slight elevation was formed, it presented a sort of backdrop that opposed the regular wind flow, which in turn resulted in the formation of vortices and the constant accumulation of deposits along a strip of land, in the area where the two lava layers meet, which was already partially occupied by vegetation and water. In this climatic condition basalt alters very quickly and the contact surface of the successive lava flows in favourable hydrogeological conditions, and with a certain feed continuity, represents the only possible hydric flow.

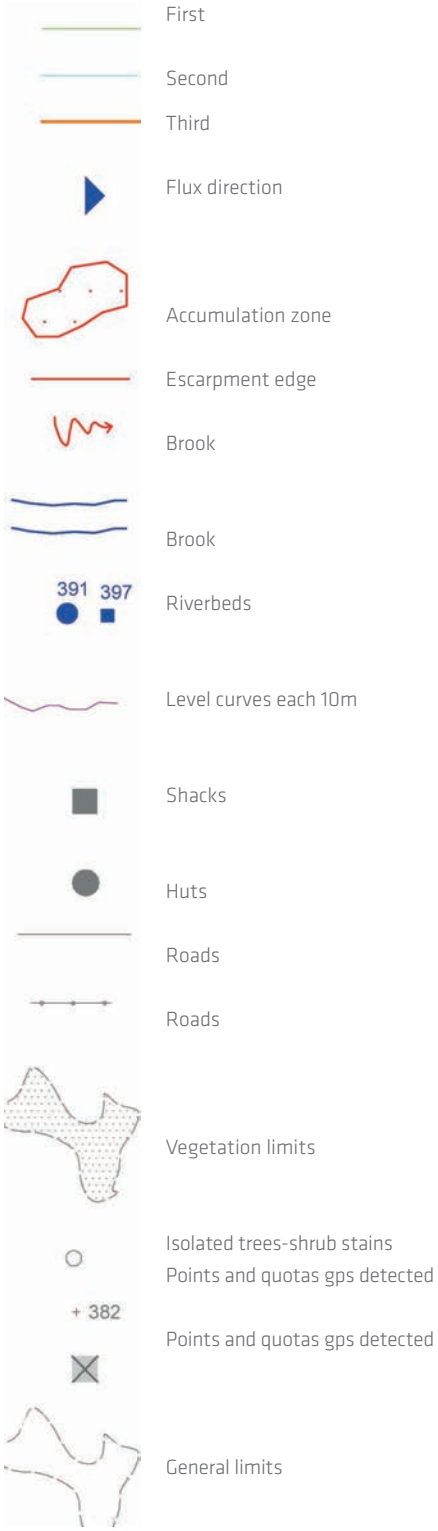
A typical form of aeolian accumulation was thus originated and consolidated over time, such as the dune that has taken on an increasingly accentuated parabola shape; wind deposition increased the thickness of the upper horizon of the ground. Similar situations are visible also at a larger scale and usually generate preferential water flows or geological-structural situations favourable for their exit in the form of springs. Specifically, it can be said that regarding the vast area which surrounds Loiyangalani, the strong control exerted by tectonics on the drainage system has led the waters to flow along the main fractures of the most recent structural system in NW/SE and NE/SW directions. Along this network, which includes important discontinuities and intense structural deformations, the elevations are literally cut by these fractures and water, following cycles of erosion and transportation closely connected to the intensity of rainfall, continuously modifies the features of the landscape through common fluvial processes or gravitational phenomena on the sides of the narrow valley-like incisions, such as the wide flat areas that appear both in the interior and in the proximity of the Lake.

The following figure highlights the systems of channels produced by the surface runoff from the western slope of Mount Kulal, showing how almost all of this water flows into the narrow area of the Oasis, even though vast basalt plateaus are interposed between the mountains and the coast.

The hydrogeological origins of the waters of Loiyangalani

The hydric circulation patterns found in the area of Loiyangalani can be ascribed to two different feeding systems, one artesian and the other phreatic (see the Hydrogeologic infosheet), which are interconnected and therefore particularly vulnerable both in qualitative and quantitative terms.

The first one concerns the artesian aquifers belonging to the deep hydric circulation system connected to the wider hydrogeological basin, which are fed through complex feeding paths. They are connected to the depression of Turkana and to the articulated and heterogeneous set of faults and fractures that cross the Ethiopian and Kenyan plateaus.



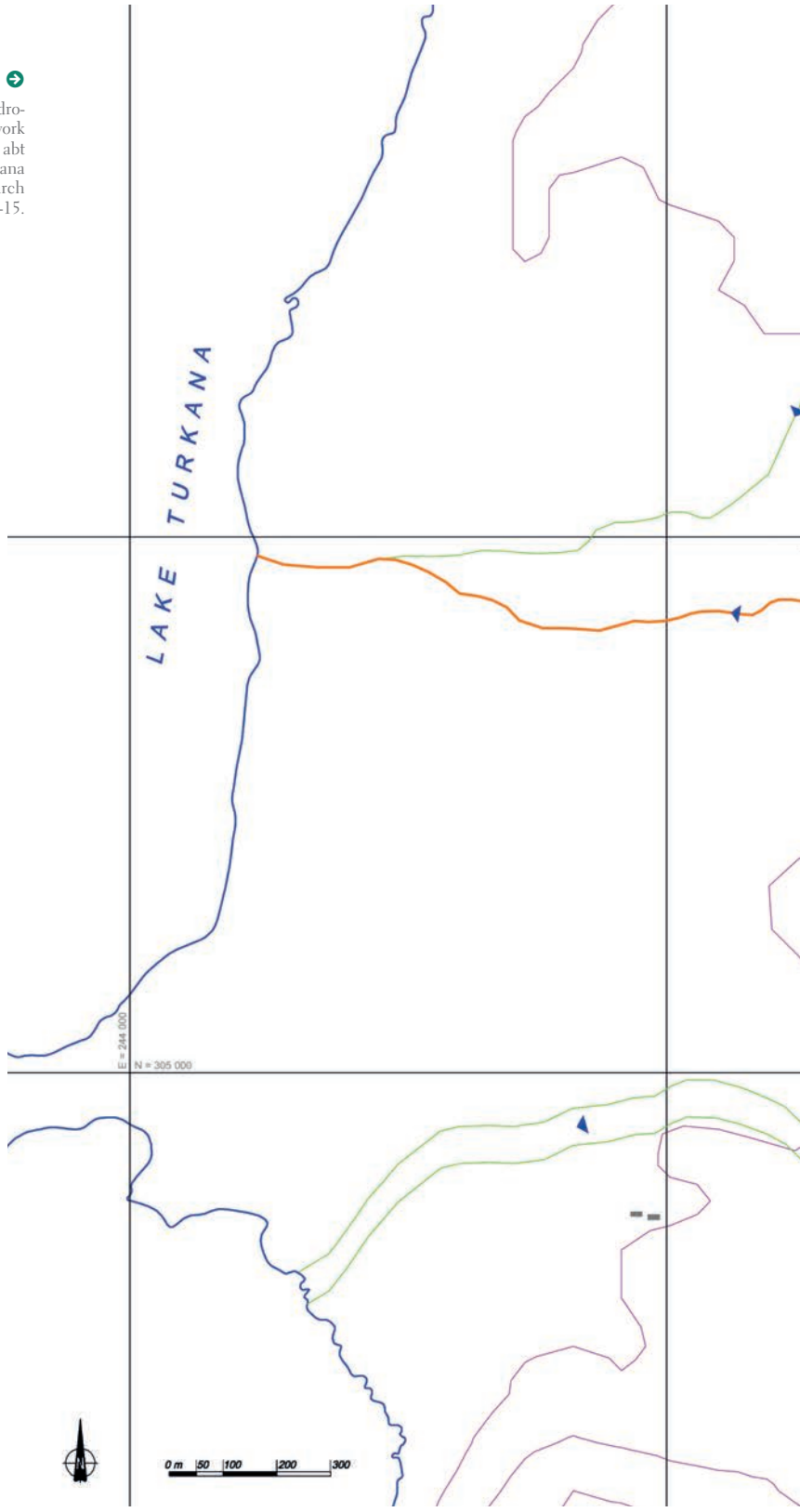


Fig. 3 Hydro-Geological Network Loiyangalani – abt 1:5.000 by the Turkana Scientific Research Group, 2010-15.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SCHOOL
ITALIAN MISSION
TURKANA VILLAGE

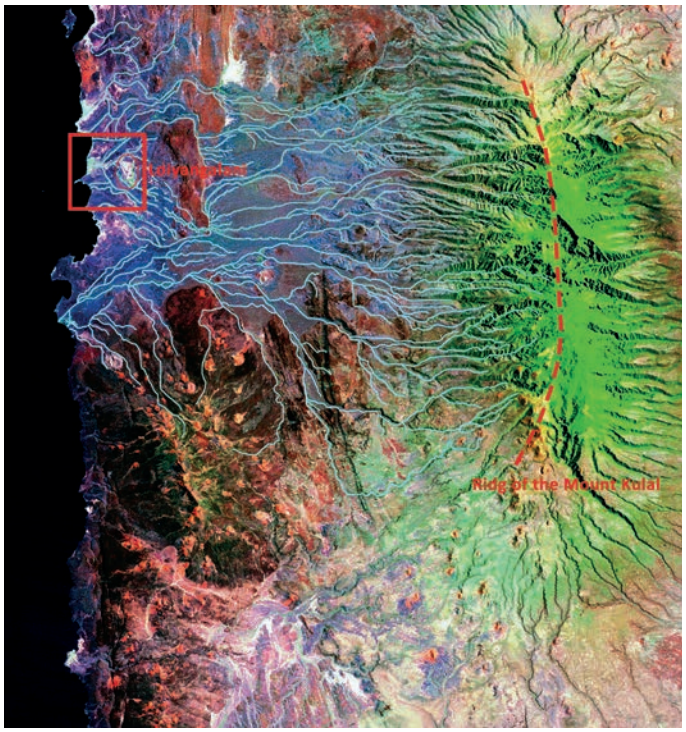


Fig. 4 General table of the most important drainage lines in the area between Mount Kulal and Loiyangalani. (By G. Ceccanti, M. Folini)

This system of flow is present mostly along the main branch of the Loiyangalani Oasis, with approximately ten hot springs (with temperatures around 40°C) with varying levels of outflow that are aligned in a contact zone that runs more or less in a north/south direction. In this contact zone water flows very close to the surface of the ground, thus allowing vegetation to live and develop.

Water coming from this thermo-mineral circuit is characterised by low conductivity values and by a normal average content of sodium, calcium and magnesium, parameters which have permitted the Oasis to develop and to ensure acceptable conditions for living beings.

This water is thus a fundamental resource for the life of the Oasis, unlike water coming from Lake Turkana, which is highly alkaline and contains elevated levels of sodium, as well as low amounts of calcium and magnesium, completely unfit for human use, as well as for watering animals and for irrigation, except after costly and complex treatments.

The second one regards more or less continuous and superficial phreatic aquifers which are present in the context of alluvial deposits that fill the *wadi*[2] and are connected to the scale of the pluvial basin of Mount Kulal. In this region the average rainfall is between 200 and 250 mm/year and the evaporation rate due to the elevated temperatures is very high, and therefore under normal conditions the amount of water that infiltrates into the underground is insufficient for recharging the aquifer. However, the presence of the volcanic shield presents a largely favourable topographic variable since the difference in elevation favours the triggering of rain during the passage of warm and humid air coming from the Lake. This rain partially infiltrates the ground and feeds the deep aquifers and is partially drained by superficial fluvial layers, which are granulometrically very coarse.

This is the case regarding a large section of the area studied, and as an additional proof of the basic impermeability of the rocky substratum, the hierarchy of the superficial grid is well developed, with clearly visible main trajectories. The colluvial covering is constantly affected by runoff that can be found both in a channelled and diffused manner.

The superficial drainage network is regulated by two main outflows, two highly anastomosed channels which gradually descend from east to west, bordering the area of intervention to the north and south.

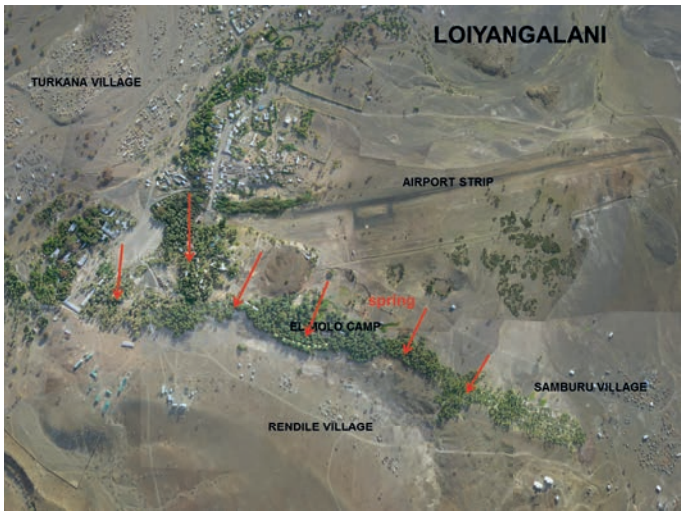
The beds of these incisions remain dry most of the year until the return of the rains, and only rarely out of season, in case of particularly intense meteorologic events. This superficial drainage network allows the rain falling continuously on Mount Kulal to reach the great lake, constantly feeding the aquifers in the relatively deep *clastic* alluvial deposits resting on the rocky substratum.

This allows a continuous flow which fills the alluvial deposits until practically a few metres from the surface of the ground, as was ascertained on-site carrying out some small excavations.

Endnotes

[1] The term craton is used to indicate the stable continental platforms which were not affected by orogenetic phenomena and which correspond to the primitive continents.

[2] A *WADI* is the bed of a seasonal river, typical of desertic or arid regions. In Kenya it is known as *LAGA*.



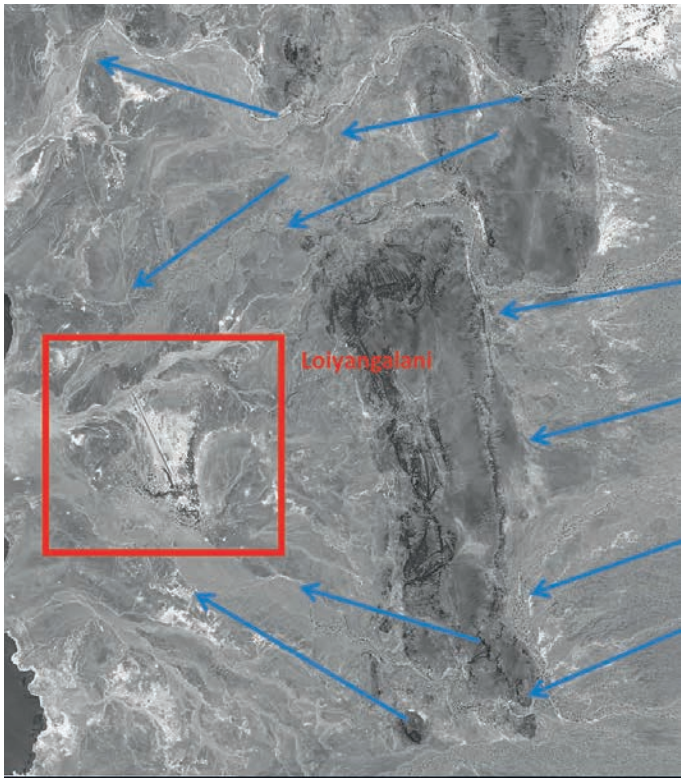


Fig. 5 Alignment of the springs around the Oasis, following a North-South direction. (By M. Folini).

Fig. 6 Pathway of the main drainage courses from the eastern zone (M. Kulal). (By M. Folini).

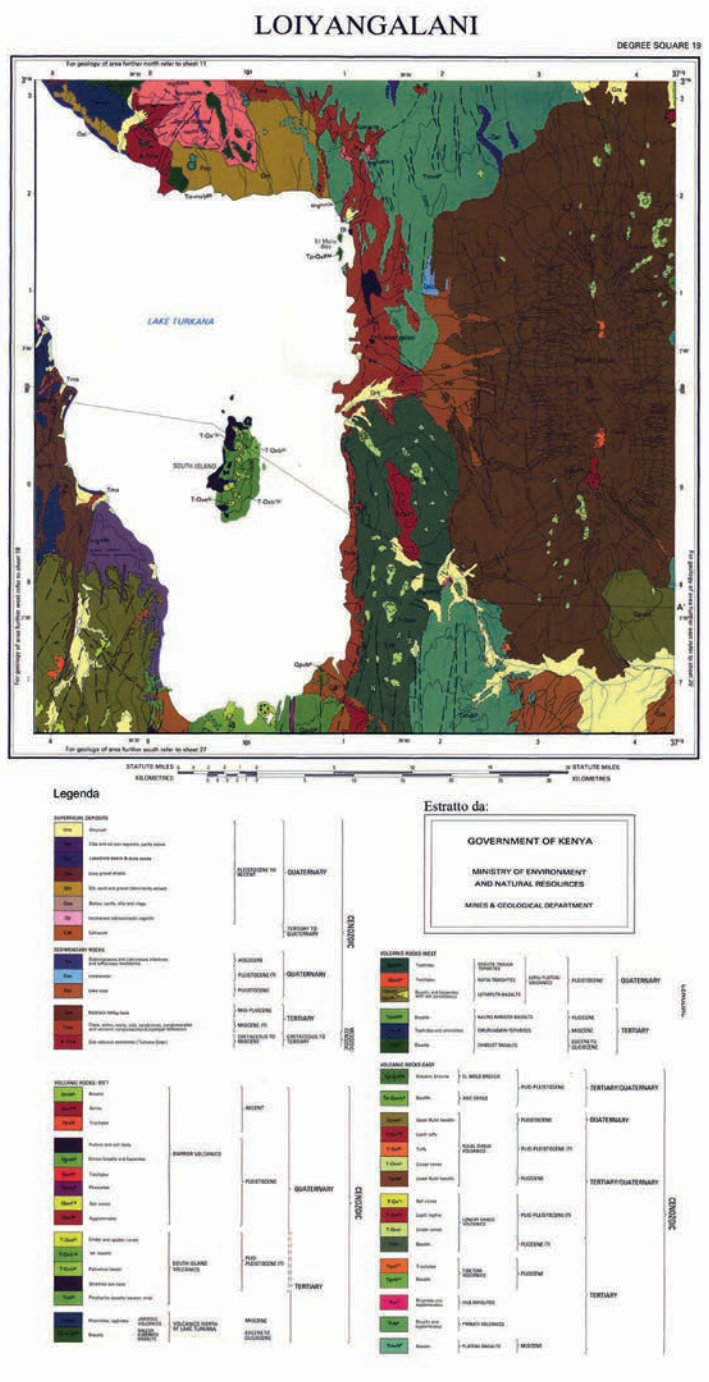


Fig. 7 Loiyangalani Geological Map, Government of Kenya, Ministry of Environment and Natural Resources, Mines and Geology Department, 1986-87.

SOME NOTIONS OF HYDROLOGY

Giancarlo Ceccanti, Marco Folini

In hydrological terms, the main feature of a geological formation is its permeability; porosity and permeability of an insterstitial or *primary* type is when the empty spaces (the pores) were originated together with the rock itself, and this is the case of the so-called *loose soils* such as silt, sand or gravel; a porosity and permeability of secondary type, instead, is when the spaces are the result of fractures in the rock.

An aquifer is a rock (or a soil) that contains extractable water in a significant amount in relation to the degree of permeability, depending on the various geological and lithological elements which condition the various forms of hydric circulation below ground. In soil which is permeable due to porosity, water is diffused in a more or less uniform manner, impregnating it completely; in rocks that are permeable due to fracture, instead, the water follows a variously ramified grid of the fractures, which act as proper hydric channels within a rocky mass that is mostly whole and impermeable. In a certain sense it can be said that the more developed is the fracture grid, the more the rock will behave as a loose ground, permeable through porosity.

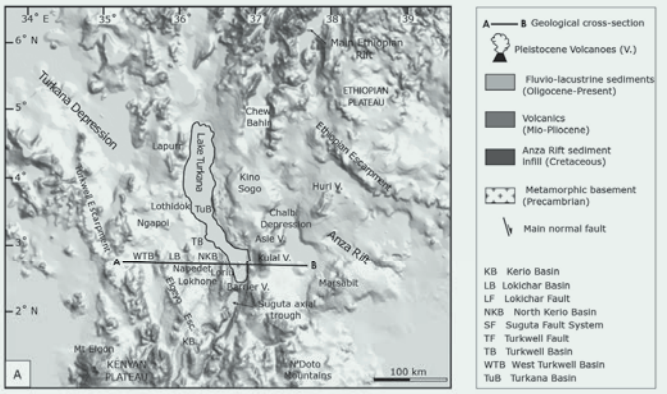
Thus the granulometry or the degree of fracture condition the capacity to contain or be penetrated by a fluid, and thus the permeability of a ground varies in relation to the sorting degree or to the level of fracturing of the material.

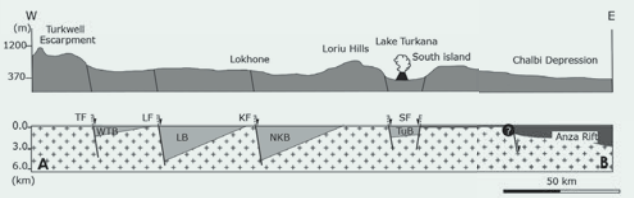
Below is a table taken from Castany, 1985, which shows the degree of variation of the coefficient of permeability K in function of the size of the grains; the permeability is represented by the coefficient K (cm/sec) which was defined as the amount of water which, under the action of a unit gradient and at a temperature of 20°, flows through a section of ground in a unit of time.

K(m/sec)	10>1x10-4	1x10-9	1x10-11
granulometry	course gravel, gravel and sand	sand, silt and clayey silt	clay
permeability	high	low	not present
formation	permeable	semi-permeable	impermeable

The permeability of an aquifer is usually greater than 1x10-5 m/s; a geological formation with a degree of permeability lower than 1x10-9 m/s is considered impermeable (aquiclude) because even when it is saturated with water it does permit its movement. A formation which permits the water to flow at a very low speed is considered a semi-permeable aquifer (aquitard).

The first aquifer found under the surface is called an unconfined aquifer (phreatic aquifer) because the water level (piezometric level) can rise or decrease freely. At a greater depth, if an aquifer is enclosed by two impermeable geological formations, it can be subjected to geostatic pressure and it is considered an artesian aquifer.





Geological Profile Turkana. Source: Vétel, W., Le Gall, B. & Johnson, T. C. (2004). Recent tectonics in the Turkana Rift (North Kenya): an integrated approach from drainage network, satellite imagery and reflection seismic analyses. Basin Research, 16, 165-181.

SUITABILITY OF WATERS FOR DRINKING AND IRRIGATION PURPOSES

Paolo Altemura, Marco Mazzoni

The suitability of water for drinking purposes is determined by the absence of microorganisms and parasites, and by the presence of other substances in quantities or concentrations which do not constitute a risk for human health; to this purpose the competent authorities (World Health Organization, European Community, and most governments) have established 'maximum concentration' levels regarding a series of chemical and physical parameters, such as the ones presented in table n.1.

If the concentration of the individual substances are not below the levels established in the table, the water must be chemically treated until the said levels are reached prior to its distribution for drinking purposes.

The suitability of water for irrigation purposes, in addition to the total amount of salts in the water, its suitability is also determined by their quality and, especially, by the reciprocal ratio of the cations present (Na^+, Ca^{++} and Mg^{++}). In order to express the activity of the sodium contained in water (and its possible participation in an exchange with the soil, in competition with calcium and magnesium) the SAR (Sodium Absorption Ratio) index is used, that is the ratio of sodium absorption. The SAR index relates the concentration of sodium, considered as a negative element for the soil, with the sum of the concentrations of calcium and magnesium, both elements which are positive for the fertility of the soil.

The greater the SAR index levels, the larger the presence of sodium in the water, and consequently the lesser its quality for irrigation purposes.

In fact, a high concentration of sodium ions in the water has an effect on the permeability of the ground and generates infiltration problems. This happens because once sodium is present in the soil in an exchangeable form it substitutes the calcium and magnesium absorbed by the clay present in the ground and causes the dispersion of the particles of the soil (i.e., if calcium and magnesium are the predominant cations absorbed by the soil it tends to be easily cultivated and has a permeable and granular structure). This dispersion causes the distribution of the aggregates of the soil, which becomes hard and compact once it is dry, reducing the speed of the infiltration of water and air into the soil, thus harming its structure.

Waters with SAR levels less than 9 do not present a significant risk of high sodium adsorption for the soil. Waters with SAR levels superior to 9, on the other hand, present a high risk for the quality of the soil.

Maximum levels for drinking water

parameter	limit value	unit of measure
ph	6,5 – 9,5	Unità di pH
conductivity	2500	µS/cm a 20°C
ammonia	0,50	mg/L
nitrites	0,50	mg/L
sodium	200	mg/L
fluorides	1,50	mg/L
chlorides	250	mg/L
nitrate	50	mg/L
sulfurate	250	mg/L

Classification of water for irrigation

		Use limitation		
Potential problems of irrigation	Parameter	none	mild to moderate	heavy
Surface irrigation	SAR	< 3	3 ÷ 9	> 9
Rain rrigation	SAR	< 3	< 3	

The waters of the Lake and of the Oasis

Springs around Samburu village. (Photo: L. Vallerini).

Paolo Altemura, Marco Mazzoni

The territory of Loiyangalani is located in the area to the south-east of Lake Turkana. Despite the presence of this enormous lake basin, due to the chemical composition of its waters, which renders them unsuitable for irrigation, as well as to the intense solar radiation and high degree of ventilation, the area is a semi-desert and water for drinking and irrigation use becomes an extremely precious resource.

The waters of LakeTurkana

As mentioned above climate conditions in the surrounding area of Lake Turkana are characterised by a high level of ventilation which, together with an intense solar radiation, have turned this region into a semi-desertic territory, increasing the desertification process. Despite the presence of the lake, water is a scarce and precious resource for the people living in the area. The composition of Lake Turkana's water is in fact not fit for drinking or watering, although some tribes use it for these purposes.

The results of the analysis of water samples from the lake carried out over the years are summarised in the following table (the levels exceeding the limits established for its use for drinking and/or watering, are highlighted in red).

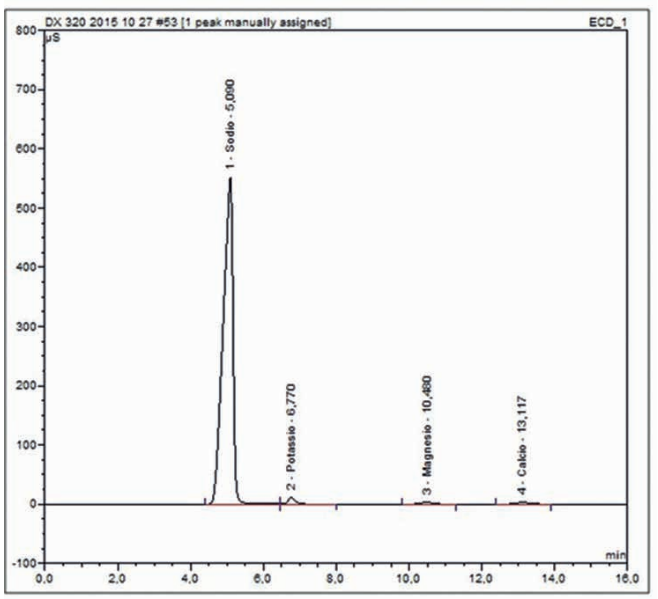
Tab. 1: Chemical composition of the waters of Lake Turkana

LAKE TURKANA WATER	PLACE OF REMOVAL				
PARAMETER	**Loiyangalani October 2006**	**Loiyangalani October 2015**	**El Molo Village September 2008**	**El Molo Village October 2015**	**Koobifora September 2008**
Temperature (°C)	n.d.	27	n.d.	30	n.d.
pH (Unità pH)	9,40	9,33	9,40	9,21	9,40
Conductivity (µS/cm at 20°C)	**3060**	**3040**	**3135**	**3120**	**3358**
Ammonia (mg/L)	n.d.	n.d.	<0,05	n.d.	<0,05
Nitrite (mg/L)	n.d.	n.d.	<0,010	n.d.	<0,010
Orthophosphates (mg/L)	n.d.	tracce	tracce	tracce	tracce

PARAMETER	**Loiyangalani October 2006**	**Loiyangalani October 2015**	**El Molo Village September 2008**	**El Molo Village October 2015**	**Koobifora September 2008**
Sodium (mg/L)	**970**	**842**	**945**	**841**	**1025**
Potassium (mg/L)	20,5	20	21	20	21
Magnesium (mg/L)	2,8	3,3	2,7	3,3	2,9
Calcium (mg/L)	7,8	6,6	5,3	6,4	5,6
Fluorides (mg/L)	n.d.	**10**	**11**	**9,8**	**12**
Chlorides (mg/L)	**518**	**414**	**510**	**412**	**385**
Bromides (mg/L)	n.d.	1,7	n.d.	1,8	n.d.
Nitrate (mg/L)	0,12	n.d.	<0,5	n.d.	<0,5
Sulphates (mg/L)	33	40	42	39	46
SAR index (°)	**53,4**	**46,9**	**57,9**	**47,5**	**62,8**

** In bold the values that exceed the guide values.*

As can be seen from the levels presented in table 3, water samples of Lake Turkana taken from the area of the Turkana tribe (Loiyangalani), as well as from those of El Molo and Koobifora, are highly alkaline and levels are near the extreme upper limit for its acceptability as drinking water due to its pH (pH levels between 9,2 and 9,4). The levels of electric conductivity at 20°C (> 3000 µS/cm), together with the high concentration of sodium ions (between 800 and 1000 mg/L), chloride (between 385 and 518 mg/L) and fluoride (between 10 and 12 mg/L), all of which values above the respective acceptable concentration limits, make this water inadequate for drinking. Special attention should be paid to the fluoride ion: this element in concentrations above 1,5 mg/L could be the cause of dental fluorosis, and in concentrations above 6 mg/L could derive in skeletal fluorosis: in other words it could be the cause of bone fragility, both in the dental and skeletal systems. Many members of the El Molo tribe, who use water from the lake for drinking purposes, suffer from this disease, as can be observed from the state of their teeth, which often appear corroded and with the presence of brown pigmentation throughout the entire dental surface.



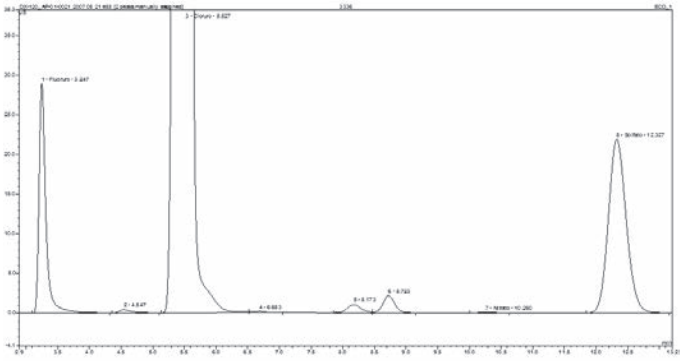


Fig. 1 Chromatogramme LC/CI anions in a water sample from Lake Turkana, collected from the village of the El Molo tribe. The signal of chloride ions (tR=5,527 min.) is placed out of scale in order to highlight the presence of fluoride (tR=3,247 min.) and sulphate (tR=12,327 min.) ions. There are also traces of orthophosphates (tR=8,173 min.) and bromides (tR=8,723 min.). (By P. Altemura).

Moreover, high sodium concentration makes the water from the lake unsuitable for irrigation purposes as well, since it has a high SAR index (SAR > 50), and low concentrations of magnesium and calcium. Some heavy metals are also present, such as iron, manganese, vanadium and arsenic, as presented in the following table:

Tab. 2: Concentration of heavy metals in the waters of Lake Turkana

LAKE TURKANA WATER	PLACE OF REMOVAL			
PARAMETER (µg/L)	**Loiyangalani October 2015**	**El Molo Village September 2008**	**El Molo Village October 2015**	**Koobifora September 2008**
chromium	< 1	3,5	< 1	3,6
nickel	1,3	< 1	< 1	3,2
copper	2,3	1,2	2,3	3,0
zinc	< 1	< 1	< 1	22
arsenic	6,3	8,0	6,3	8,0
cadmium	< 0,2	< 0,2	< 0,2	< 0,2
lead	< 1	< 1	< 1	7,4
selenium	< 0,5	8,4	< 0,5	10,3
vanadium	39,0	42,7	40,0	44,7
iron	37	103	< 10	295
manganese	1,3	< 1	< 1	142

Lake water, however, is not subject to human-related pollution; in fact, although the microbiological parameters were not determined (analysis must be carried out very soon after collecting the sample), the level of nitrates is so low that human-related pollution at a significant level can be excluded.

The water of the Oasis of Loiyangalani

Another important water resource in the region of Lake Turkana, consists in a series of small springs located in small oases: the larger and most important of which is that of Loiyangalani. The waters from these springs have been analysed in the past and the results obtained are presented in the table on the next page.
These analyses were carried out by the organisation *Wings for Earth*.

Tab. 3: Chemical composition of the waters of the Oasis of Loiyangalani (2006 - 2007)

	PLACE OF REMOVAL	
Parameter	**Loiyangalani Hot Spring (2006)**	**Loiyangalani Hot Spring (2006)**
pH (pH unit)	8,2	8,,2
Conductivity (µS/cm at 20°C)	820	n.d.
Orthophosphates (mg/L)	n.d.	2,9
Sodium (mg/L)	51	82
Potassium (mg/L)	2,4	8,3
Magnesium (mg/L)	27	23
Calcium (mg/L)	19	22
Chlorides (mg/L)	49	12
Nitrate (mg/L)	11	1,5
Sulfurate (mg/L)	20	7,9

Various water samples were collected from the villages of the Turkana, Rendile and Samburu, who live in the area surrounding the oasis of Loiyangalani, during the expeditions of 2008 and 2015. The results from their analysis are presented in table 6.
Traces of heavy metals were also found in the samples described in Table 7.

Fig. 2 Chromatogramme LC/CI cations in a water sample from Lake Turkana collected from the village of the El Molo tribe. The intensity of the signal of sodium ions (tR=5,090 min.) shows the clear prevalence of the concentration of that substance compared to those of potassium, magnesium and calcium. (By P. Altemura).

Fig. 3 Water distribution point Samburu village. (Photo: L. Vallerini).

Fig. 4 Protected Hot Springs. (Photo: P. Altemura).

From the values reported in tables 6 and 7, it is possible to deduce the following considerations:

- All the waters from the oasis which were analysed are comparable to each other and the degree of concentration of the parameters measured are all within acceptable levels for drinking purposes.

The temperature range is between 35°C and 40°C and the pH has an average value of 7,7.

- Electric conductivity at 20°C presents values between 500 and 700 µS/cm, which is typical of medio-mineral waters, with the presence of normal levels of sodium, calcium and magnesium ions.
- Waters would not appear to be subject to human-related pollution since, although microbiological analyses were not carried out, the low concentration of nitrates excludes any human or animal-related pollution.
- A slightly higher saline content is measured in the water used at the Samburu village, which is also the most distant from the springs; in fact the level of conductivity is slightly higher (600 – 700 µS/cm at 20°C, instead of 580 µS/cm at 20°C), and so are the concentrations of sodium (117 mg/L above the average 92 mg/L) and chloride ions (62 mg/L above the average concentration of 48 mg/L).
- The SAR Index presents a value of < 3 for all the analysed samples, which prove that waters from the oasis are also adequate for irrigation.
- There is practically no presence of heavy metals, with the exception of some traces of chromium and selenium. Special attention is due to vanadium, whose average concentration in the waters analysed reaches 51 µg/L, which is slightly over the limit of acceptability in water used for human consumption. The Environmental Protection Agency (EPA, 1997), in fact, has proposed a maximum recommended concentration of 50 µg/L, a level that has subsequently been adopted as well by the World Health Organization, the European Community and the Italian Government, through Legislative Decree 31/2001, and subsequent modifications and additions.

Spring waters that reache the villages of the three tribes are all within the oasis on the highest area with respect to the lake; the difference in altitude is only a few meters high yet enough to let water

Fig. 5 Mulugu medicinal spirings. (Photo: L. Vallerini).
Fig. 6 Ngobole Spring. (Photo: P. Altemura).

Fig. 7 Waterlogged basin at the Ngobole Oasis. (Photo: P. Altemura).

Tab. 4: Chemical composition of the waters from the springs in the Oasis of Loiyangalani (2008 and 2015)

	PLACE OF REMOVAL (September 2008, October 2015)									
Parameter	**Protected Hot Spring**	**El Molo Lodge**	**Oasi Lodge**	**Primary School**	**Italian Mission**	**Turkana Village nord side**	**Turkana Village south side**	**Turkana Village south side (2015)**	**Samburu Village approved**	**Nursery**
Temperature (°C)	(36,5)	(37,8)	(39,0)	n.d.	n.d.	(37,5)	n.d.	(35,8)	(36,5)	n.d.
PH (pH unit)	7,7 (7,5)	7,8 (7,6)	7,8 (7,7)	7,7	7,8	7,6 (7,5)	7,5	(7,7)	7,7 (7,6)	7,2
Conductivity (µS/cm at 20°C)	577 (590)	581 (630)	596 (554)	577	573	574 (590)	577	(593)	654 (630)	579
Ammonia (mg/L)	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05
Nitrite (mg/L)	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010
Orthophosphates (mg/L)	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05
Sodium (mg/L)	91	94	95	92	92	92	92	89	117	92
Potassium (mg/L)	5,0	5,0	5,0	5,3	5,0	5,0	5,0	5,8	5,5	5,3
Magnesium (mg/L)	25	25	25	24	24	24	25	26	25	25
Calcium (mg/L)	18	18	19	18	18	18	19	19	20	18
Fluorides (mg/L)	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5
Chlorides (mg/L)	48	49	50	48	48	48	48	51	62	48
Nitrates (mg/L)	17	18	17	18	17	16	16	17	20	18
Sulphates (mg/L)	21	22	23	22	22	21	22	21	28	21
SAR index (°)	2,29	2,37	2,37	2,35	2,35	2,35	2,30	2,19	2,90	2,32

In parentheses are reported the values of the parameters determined in the field during the expedition of 2015.

Tab. 5: Concentration of heavy metals in the waters from the springs in the Oasis of Loiyangalani (2008 and 2015)

Parameter	PLACE OF REMOVAL (September 2008, October 2015)									
U.d.M. µg/L	Protected Hot Spring	El Molo Lodge	Oasi Lodge	Primary School	Italiana mission	Turkana Village north side	Turkana Village south side	Turkana Village approvv. south side (2015)	Samburu Village approved	Nursery
chromium	5,7	5,7	5,1	5,4	5,2	5,3	5,7	5,2	3,6	5,5
nichel	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
copper	< 1	< 1	< 1	< 1	1,3	< 1	< 1	< 1	< 1	< 1
zinc	2,5	< 1	1,8	< 1	14,0	2,0	7,6	1,2	<1	<1
arsenic	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
cadmium	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
lead	< 1	< 1	< 1	< 1	< 1	< 1	11,6	< 1	< 1	< 1
antimony	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
selenium	1,5	2,0	1,9	1,5	1,3	1,7	1,1	1,0	1,9	1,5
vanadium	52,1	53,1	51,7	51,6	50,0	52,2	50,0	51,0	43,7	52,9
iron	< 10	< 10	19	< 10	< 10	< 10	< 10	< 10	20	< 10
manganese	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
mercury	< 0,1	0,3	0,4	0,1	< 0,1	0,1	0,1	< 0,1	< 0,1	0,3
tin	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

flow toward the distribution points located at the edges of the villages (supply for the Turkana village to the south and for the Samburu village to the north).

The similar composition found in all analysed water samples indicates that the springs have a common origin which, considering the differences between the two types of water, are not connected with that of lake Turkana. As highlighted before, Oasis waters originate in Mount Kulal, which is approximately 20 kilometres from Loiyangalani. The most important water source in terms of supply, approximately 20 Litres/minute, was partially protected by an enclosed concrete structure (protected Hot Spring) and partially accessible (unprotected Hot Spring). With the exception of the tubing which carries water to the distribution points on the edge of the villages of the Turkana and Samburu tribes, the other spring waters of the oasis flow through some open-air, unprotected 'gorili', that is rills or ditches which descend toward the lake without ever reaching it, becoming dispersed as they reach the flat lands at the end of the oasis. These waters are especially vulnerable to man-related pollution, particularly in view of the demographic increase over the past few years, and of the consequent settlements that have grown without appropriate control. Some dwellings were even built above the springs and this presents a great risk since it can endanger the entire drinking water supply of the oasis, unless a proper tubing system is installed to contain and remove domestic waste water.

However, comparing the concentration of the various parameters determined in 2006 to those up to 2015, it can be seen that there have not been significant variations in the composition of spring waters in Loiyangalani, so that the current water system of the oasis can be considered sufficiently protected from man-related pollution.

The other waters in the area surrounding Loiyangalani

In the territory between Loiyangalani and the village of the El Molo tribe, to the north-east of the line that connects the two villages, there are several springs from which water was collected and analysed during the missions of 2008 and 2015. The results of the analyses carried out in 2008 at the Tuscan Regional Environmental Protection Agency (*Agenzia Regionale Protezione Ambientale della Toscana*, ARPAT), and on site in 2015, are summarised in tables 8 and 9:

Tab. 6: Chemical composition of the water from the springs in the area surrounding Loiyangalani (years 2008 and 2015)

parameter	PLACE OF REMOVAL (September 2008, October 2015)					
	Mulugu Medicinal Spring (2008)	Mulugu Medicinal Spring (2015)	Sprite (2008)	Sprite (2015)	Oasi Ngobole (2008)	Oasi Ngobole (2015)
Temperatura (°C)	-	29	-	36	-	22
pH (Unità pH)	9,5	9,4	6,8	5,5	8,7	6,9
Conducibilità (µS/cm a 20°C)	11640	10825	4289	4612	698	807
Ammoniaca (mg/L)	< 0,05	-	< 0,05	-	1,1	-
Nitriti (mg/L)	< 0,010	-	< 0,010	-	< 0,010	-
Ortofosfati (mg/L)	< 0,05	-	< 0,05	-	< 0,05	-
Sodio (mg/L)	5000	-	1270	-	119	-
Potassio (mg/L)	86	-	43	-	7,1	-
Magnesio (mg/L)	2,1	-	114	-	32	-
Calcio (mg/L)	0,7	-	72	-	20	-
Fluoruri (mg/L)	0,7	-	0,6	-	< 0,5	-
Cloruri (mg/L)	2120	-	477	-	57	-
Nitrati (mg/L)	< 0,5	-	< 0,5	-	8,9	-
Solfati (mg/L)	1000	-	209	-	13	-
Indice SAR (°)	158	-	21,5	-	2,70	-

Tab. 7: Heavy metals presnt in the water from the springs in the area surrounding Loiyangalani

parameter	PLACE OF REMOVAL (September 2008)		
U.d.M. µg/L	Mulugu Medicinal Spring	Sprite	Oasi Ngobole
chromium	7,6	3,6	1,0
nichel	< 1	1,2	< 1
copper	2,1	< 1	< 1
zinc	< 1	< 1	< 1
arsenic	28,0	2,4	< 1
cadmium	< 0,2	< 0,2	< 0,2
lead	< 1	< 1	< 1
antimony	< 1	< 1	< 1
selenium	16,9	3,9	1,9
vanadium	181	1,2	70
iron	< 17	21	23
manganese	< 10	23	25
mercury	0,2	< 0,1	< 0,1
tin	< 1	< 1	< 1

The waters recorded in the table can be grouped into three main typologies on the basis of their composition:

• Mulugu Medicinal Spring

This spring is located in a wide, rocky and sun-drenched depression. Water springs from the ground near some rocks which mark the north-east boundary of this area at a temperature above 30°C and at a slow flow rate of only a few L/minute. The water is highly alkaline (pH=9,5), has a high level of electric conductivity at 20°C (> 11000 µS/cm), and sulphates (1000 mg/L), and is not subject to man-related pollution. Microbiological analysis is absent also in this case, but the level of nitrates is so low that it excludes any meaningful human-related pollution. This type of water is not adequate for irrigation since it is very high on the SAR index. Compared to the other waters analysed, this water is characterised by the presence of various heavy metals, among which arsenic, selenium and vanadium.

Leaving this first spring in the direction of lake Turkana, the dip is almost enclosed by two rock concretions. The sandy ground becomes rich in salt, as if it was covered by a white crystalline dust. Water flows out from several points in the ground, all near each other and at a temperature of approximately 29°C; the waters join to form a rivulet which flow toward lake Turkana without, however, reaching it. The abundant salt is probably a carbonate that is soluble in water, since the pH of the water is 11,2 and the electric conductivity at 20°C is 10700 µS/cm. This water is also obviously not adequate either for drinking or irrigation purposes.

• 'Sprite' Spring

This spring is located in the same depression as the preceding spring, a few hundred metres to the north of the Mulugu Medicinal Spring. It also flows from the ground at a slow rate and with a temperature of approximately 36°C, yet it is clearly different from the previous spring; in fact the water is naturally effervescent and for this reason the pH is much lower than that of the other waters in the area (pH= 6,8); it has a high level of electric conductivity at 20°C (> 4000 µS/cm), due to the presence of high concentrations of sodium (1270 mg/L), magnesium (114 mg/L), chlorides (477 mg/L) and sulphates (209 mg/L). This type of water, therefore, does not have the necessary qualities to be used for. Regarding the presence of heavy metals, although it is relatively close to Mulugu spring, this water is very different and has a low presence of heavy metals, including vanadium.

The 21,5 SAR index indicates that this water is not suitable for irrigation either.

• Ngobole Oasis Spring

This spring is located in a trackless area a few kilometres away from the previous springs. The flow rate is more constant and develops a small waterlogged basin (with an extension of only a few m2 and over a metre deep), thanks to which a few shrubs manage to survive. From an analysis carried out on a sample collected during the 2008 mission, it was determined that this type of water is slightly alkaline (pH = 8,7), however, the values of the remaining parameters are in line with those observed for the various waters in the oasis of Loiyangalani, and thus appropriate for drinking purposes, although the concentration of vanadium is slightly above the limit. However, already in 2008 the spring was very vulnerable to possible pollution (ammonium ions were found) due to the easy accessibility to the spring of some animals present in the area. The vulnerability of the spring was demonstrated during the 2015 mission: during the analyses carried out on site, a few dozen dromedaries were spotted above the basin, drinking water exactly at the place where the water flows out from the rocks. The basin was fed by a stream with water that was clearly polluted with the urine from the animals, to the point that the pH of the water sampled resulted highly acid (pH = 6,9) and the level of electric conductivity equal to 807 µS/cm.

In any case the 2,7 value on the SAR index indicates this water as suitable for irrigation purposes.

The quality of waters and their use

The quality of the water from the springs in the area of Loiyangalani is related mostly to the volcanic nature of the region: in some cases the temperature, and in other the presence of high saline levels, associated to the value of the pH and to the presence of certain heavy metals, seem to confirm this hypothesis. The quality of the waters of lake Turkana, instead, seems to depend on two sources: the lake is fed mostly (approximately 90%) by the river Omo, whose course is almost entirely contained within the borders of Ethiopia (the water reaching lake Turkana was reduced significantly by the construc-

Fig. 8 Main springs inside the Oasis of Loiyangalani. (Photo: L. Vallerini).

tion of the huge dam Gigel GIBE III and will diminish even more with the building of two other dams, GIBE IV and GIBE V, currently in design stage), but also, to a lesser degree, by rainwater that reaches the lake from the surrounding areas during the rainy season. The waters of the Omo river, with its sediments consisting of silt and clay, combine with the lavic rocks of the lake, which could be one of the reasons for the anomalous levels of pH, fluorides and salinity (sodium, chlorides, etc.), and of some heavy metals, especially vanadium. The high concentration of salts is also due to high solar radiation, high temperatures and intense ventilation, which are almost constant throughout the day (at night the intensity of the wind increases due to the displacement of the heat absorbed by the water of the lake during the daytime toward the interior rocky areas).

Due to the chemical characteristics of the lake and spring waters, which have a high saline content, it is evident that the use of these waters for drinking or irrigation purposes is impossible without a chemical-physical treatment.

The springs within the oasis of Loiyangalani, instead, are adequate for both drinking and irrigation. Their origin is clearly different to that of the other waters: they most probably come from mount Kulal, which stands not far from the area of Loiyangalani. During their underground course they most probably come in contact with lavic rock which gives the water a high temperature (over 30°C), but do not alter its composition in any significant manner.

The quantity of drinking water available in the region of Loiyangalani does not seem to be enough to satisfy the needs of the communities who live in the study area of this research. Therefore there are necessary specific actions, some of which have already been described, in order to:

- Increase the use of spring waters in Loiyangalani, limiting as well the rate of dispersion of water in the ground, which often is not controlled.
- Dig at least one well in the village of the Turkana, which has the highest population density in the region of Loiyangalani.
- Obtain groundwater for drinking purposes for the village of El Molo, through the drilling of an artesian well.

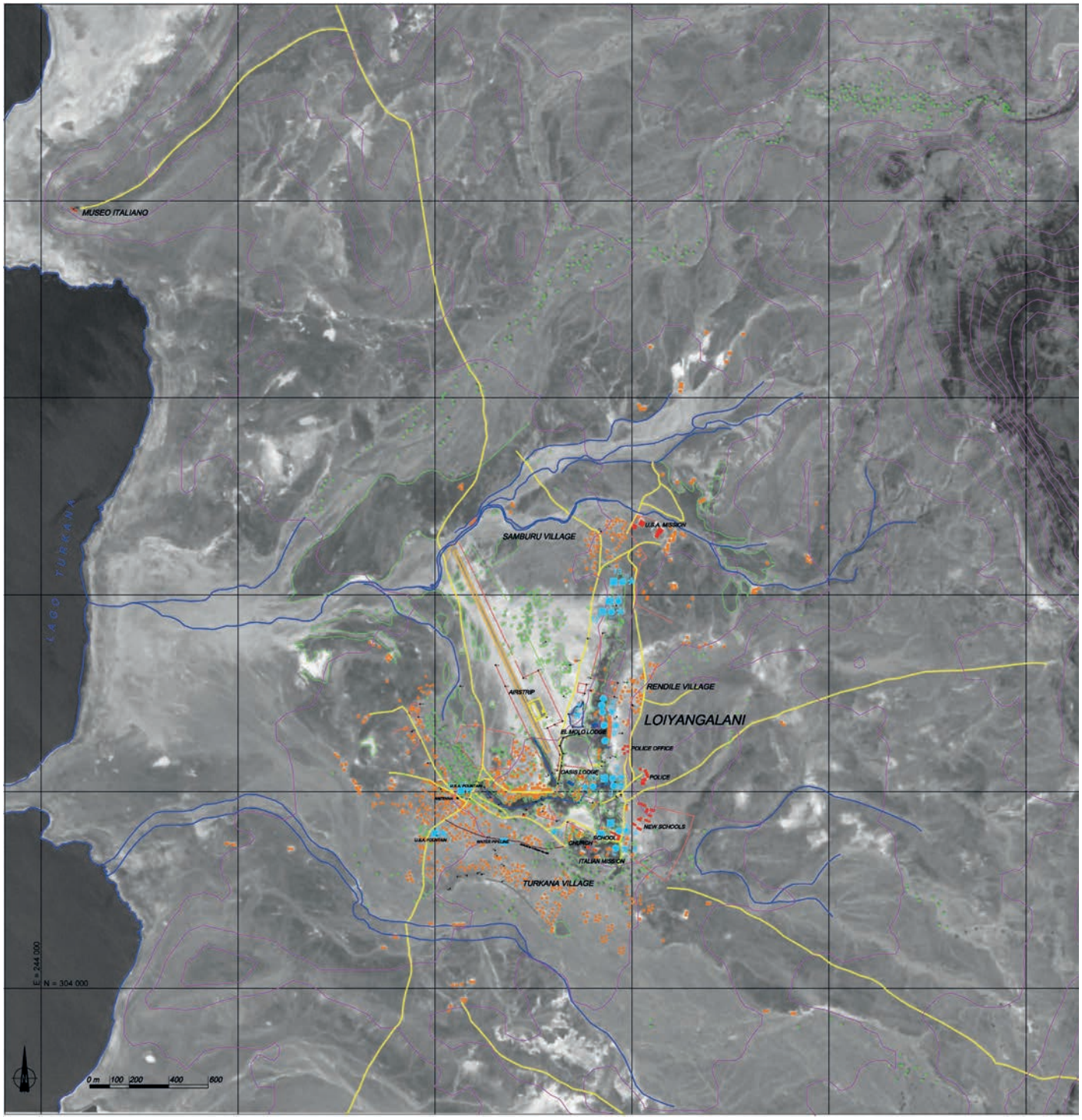
The idea of transforming the water from lake Turkana into drinking and irrigation water through the reduction of the concentration of fluorides and other salts present, as well as through modifying its pH, does not seem feasible due to the complexities involved in the construction of the treatment facilities and their proper maintenance.

In order to fulfill the objective of reforesting the oasis it is also necessary to make the soil fertile through a correction of the existing saline composition. For that purpose it would be necessary to have access to the necessary amount of water with the adequate saline composition: in particular water with a low sodium content (SAR index < 9). And, as we have seen, water of this nature is only found at the oases of Ngobole and Loiyangalani. The amount of water, however, is still insufficient for its large-scale use. The water available in Loiyangalani seems sufficient, however, for satisfying the drinking water needs of the communities present in the area.

The largest resource of water is that of lake Turkana, yet its chemical composition, as has been explained above, makes its direct use impossible, and the establishment of treatment facilities for its use for drinking and irrigation purposes seems to be out of the question.

Fig. 9 Quality of the Waters - 1/5.000 by the Turkana Scientific Research Group, 2010-15.

- SOURCE POINTS
  - 2 – Hot Sping (protected)
  - 3 – Hot Sping (non-protected)
  - 5-6 – El Molo Lodge
  - 8 – Italian Mission
  - 10 – Oasi Lodge
- GRIPPING POINTS AND REPLACEMENT
  - 9 – Turkana Village Nord (american source)
  - 11 – Turkana Village South (american source)
  - 12 – Samburu Village
  - 13 – Samburu Village
- SURVEY POINTS no.14



The soil: pedology and survey

Soil erosion along the Oasis. (Photo: L. Vallerini).

Fig. 1 Diagram with landscapes observed in the oasis of Loiyangalani. Recent alluvial terraced landscapes and current wadi (laga). (By: P. Magazzini, L. Nofroni)

Piero Magazzini, Ugo Wolf

Vegetation and land cover

Cultivations are not widespread in the oasis except for some small vegetable gardens near dwellings. The area is divided into a central elevated zone, the heart of the oasis, where most of the local springs are located, as well as most of the doum palm groves (*Hyphaene thebaica* L.), and the surrounding area, including degraded areas and poor vegetation surfaces. This area is clearly degraded by erosion and overgrazing by sheep and goats; the dominant tree species here is Acacia Tortilis L.

Grass species are practically limited to some fenced and protected private properties, such as home gardens within the areas of urban expansion. The oasis itself (in those areas with trees) is in fact highly urbanised on almost all of its territory, with stable buildings, many of which in masonry, including private houses, lodges and resorts, as well as public buildings and the Catholic mission.

Outside of the oasis, other scattered groups of trees (with doum palms and bushes) are situated in the central plain, along and to the east of the landing strip. These are probably what remains of more extensive palm groves, including highly degraded and discontinuos sparse grass formations.

Other natural herbaceous formations, with sparse bushes and small groups of doum palms, are still present in the wadi to the north of Loiyangalani.

The increasingly widespread presence of Prosopis (*Prosopis L. sp.)* must be highlighted. Locally known as Algarroba, it is a bush belonging to the family of the mimosaceae, highly invasive, not much liked by livestock, but increasingly used for fencing private areas. The ease with which this plant becomes widespread puts the other tree and bush species in the area at risk. It is therefore important to limit their diffusion as much as possible, in order to avoid an overwhelming invasion which in other parts of Africa has become a great problem (as in Somaliland, for example).

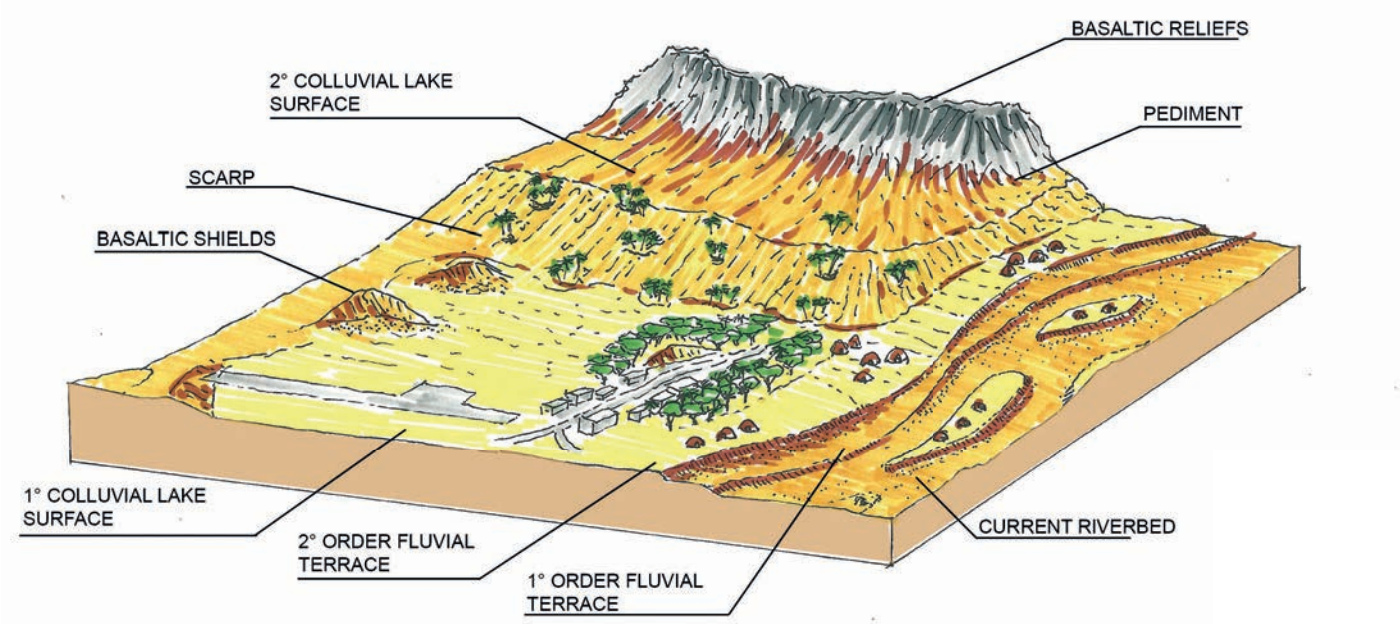


Fig. 2 View of recent alluvial terraces with the presence of colluvium. (Photo: P. Magazzini).

Fig. 3 View of landscape of the terraced surfaces and of the current wadi-landscape of ancient lacustrine deposits. (Photo: P. Magazzini).

Forms and landscape

After a first impression the area appears mostly uniform, a gently rolling terrain with wide, almost flat surfaces with slight inclinations surrounded by rocky basalt hills.

Looking in detail it is possible to identify a series of different morphological surfaces, some well developed and others hidden by past and present morphogenetic processes.

The oasis of Loiyangalani and its surroundings can in fact be divided into three main landscapes, to which correspond different soils and uses.

Recent alluvial terraced landscapes and current wadi (laga)

The area of the oasis is surrounded, both to the north and south, by two seasonal wadis (locally known as 'laga') which, during the rainy season drain the superficial waters descending from Mount Kulal, which is located approximately 25km to the east. The area is characterised by wide riverbeds with a variety of intersecting multichannels which highlight the large amount of water present during the rainy season, and by a recent and present sedimentation of mostly coarse materials (basaltic gravels and stones), as well as some moderately rounded elements.

Next to the current riverbed there are at least two orders of recent fluvial terraces. The first, lower and formed on recent deposits, is less noticeable than the current riverbed, which is constituted by coarse elements, mostly basaltic stones, and is occasionally submerged during more intense rainfall events. The second, approximately 4 m higher than the current riverbed, is connected to the more recent terrace by a small escarpment. Wide and flat, it is not subject to submersion and is usually mostly occupied by the huts of the Turkana and Samburu villages.

Landscape of ancient lacustrine deposits

Proceeding toward the hills, a wide flat surface is found, joining the second fluvial terrace. This is the area in which the main settlements in the oasis stand, and where the landing strip has been located. This surface is probably a lacustrine sedimentation area, flattened and buried by a shallow layer of colluvial sediments coming from the nearby basaltic hills. Rounded moulds are scattered on the surface and represent basaltic shields, that appeared after the deposition of the lacustrine sediments.

The flat lacustrine surface ends abruptly in a steep 20 to 40 m high escarpment, which are the steeper slopes in the surveyed area, reaching up to 20% and 35% degrees. The escarpment is covered with trees and bushes, with a prevalence of the doum palm, and most of the springs in the oasis are located here. The springs probably follow a fault line, producing an elongated elevation with small slopes that face the coastline (approximately 2,4km away). The escarpment occurs on the lacustrine sediments, with clay and basaltic outcrops and with colluvium with coarse basaltic material. The escarpment is subject to sheet erosion, especially where the vegetation cover is missing, due in part to natural, but mostly to human-related causes.

A second quite extended flat surface is found at the top of the escarpment with similar features to the lower lacustrine surface, which was probably dislocated upward by the shifting of the fault. It is by coarse colluvial material coming from the basaltic hills, characterised by scattered and discontinuous grass pillows growing on silty loam deposits, probably of aeolian origin.

Hills and basaltic shields

The higher flat lacustrine surface runs above a short pediment made of rock debris from the basaltic hills that enclose the oasis to the east, where bare soils are dominant, (excluding a few specimens of acacia tortilis). The surface of the oasis and its surroundings seems to also include a scattering of basaltic outcrops which form modest low reliefs.

Soil survey

Phase 1 – Preliminary investigation on soils

The first phase of the soil survey, undertaken in an overall area of approximately 365 hectares, consisted in the identification of the main pedo-landscapes into which the area is divided. The on-site field reconnaissance, supported by the medium-resolution satellite image (at a 1:5000 scale, but with a considerably lower pixel resolution) was subsequently completed by the interpretation on a semi-controlled, true colour photo-mosaic, made especially during the mission and reproduced at the same 1:5000 scale. Due to the short amount of time available, a free survey approach was adopted, choosing through profiles and observations representing the distribution model, composed by:

- type of parent materials and substrata;
- erosional and depositional processes in relation to the geomorphological positions;
- main modes of land use.

In this phase 9 profiles, mini-pits and quick field observations were carried out; 8 were analysed.

Phase 2 – Preliminary photo-interpretation

The preliminary pedolandscape photo-interpretation Units was carried out on aerial images on a semi-controlled, true colour photo-mosaic. 13 soil units and 2 non-soil units (quarries, urban areas and landing strip) were identified and mapped.

Following are the simplified map keys:

R1o: Dominant basaltic rock outcrops (with olivine and plagioclase), briefly alternating with very shallow and skeletal soils. No vegetation cover.

R1s: Dominant shallow and skeletal soils on basaltic rocks (with olivine and plagioclase). Practically no vegetation, with rare scattered bushy trees.

R1d: Dominant deep soils on basaltic rock (with olivine and plagioclase). A good dense, well-developed and multispecific trees layer, with fenced home gardens. The Unit comprises some urban settlements (lodges and resorts).

R1e: Eroded phase of Unit R1d. Land cover and land use same as above, yet with a more degraded trees cover, less dense and dominated by doum palms.

R2s: Dominant, medium-deep to shallow soils on basaltic rock (with plagioclase). Groups of trees with medium-low density and elements of degradation present, dominated by doum palms, also somewhat degraded. This Unit includes areas of urban development and expansion, with fences and home gardens.

R2e: Eroded phase of Unit R2s. The existing vegetation, both trees and bushes, are clearly degraded and some areas are barren. Also this Unit includes areas of urban development and expansion.

AL: Loose deposits of sand and gravel, often of large sizes, with many pebbles, from very recent and present alluvial deposition. Beds of wadi (local term is 'laga'). This Unit is almost entirely lacking in vegetation, with the exception of scattered grass formations and doum palms in the wadi north of Loiyangalani.

AT: Deep sandy soils with large amounts of thick gravel and pebbles, on terraced alluvial deposits, seldom subject to brief seasonal flooding. The Unit marked with an asterisk (AT*) may yet be subject to flooding, but only for brief periods and in large amounts during higher floods. This Unit includes areas with recent urban development. Most areas are almost completely barren, with some diffusion of urban trees (artificial plantations), rare acacias and small fenced areas in which home gardening practiced under tree formations with a good density.

PEW: Dominant saline-sodic soils, deep and moderately well drained, with a tendency to form crusting on colluvial and run-off deposition surface. Dominant barren surfaces, with discontinuous

grass formations in pillows and doum palms groups. It comprises areas including urban settlements area to the north.

C: Dominant saline-sodic soils, deep, subjected to colluvial deposition at the base of the elevations. This Unit lacks a dense tree presence, yet has grass formations that are linked to contributions related to water run-off from the springs. A few areas include degraded tree groups (mostly doum palms and bushes).

Ce: Shallow soils on colluvial deposits, with a high degree of topsoil degradation often eroded, with outcropping of parent materials on surface. Vegetation almost absent, with rare and discontinuous grass pillows.

EH: Highly eroded (water erosion) and very degraded surfaces, including small escarpments due to fluvial erosion; practically without soil or with outcropping of parent materials. Small, discontinuous and very degraded patches of trees. This Unit includes a highly urbanized and degraded area (football pitch).

Eg: High degree of channel water erosion forming gullies. No vegetation.

Q: Quarries.

U: Artificial accumulations and materials transported for building the landing strip.

Phase 3 – Final survey and mapping

In this phase, carried out in 2015, the soil survey was completed with new observations and the digging of 9 new soil profiles, completely sampled and analysed.

The description of the soils and the results of the analyses are available upon request to the authors.

Ground controls allowed to produce the final soil map, at a 1:10,000 scale, carried out on high resolution (10x10m) satellite images obtained in 2013.

The soil survey completing the necessary observations for defining the soil typologies and qualities, with identification of 11 soil map Units, homogeneous in terms of the distribution of soils, morphological features, lithology and presence of vegetation. The figures illustrate the distribution of soils in the area of the oasis.

The soils of Loiyangalani and their formation processes

The soils of Loiyangalani are developed basically on three different bedrocks:

- recent pyroclastic volcanic rocks (Quaternary age) of basaltic origin rich in olivine and plagioclase
- sub-recent and present alluvial deposits, also derived from materials of a very similar lithologic composition (basalts).
- buried silty lacustrine sediments.

Two other parent materials seem to be widespread:

- a discontinuous layer formed by colluvial deposits derived by the dissolution of past soils on volcanic rock.
- an etch-washed plain and colluvial deposition of relatively fine materials on lacustrine deposits around the artificial elevation of the landing strip.

These parent materials are very important since, on the one hand, they show diffuse sheet erosion phenomena which have happened in the past and which continue to have an effect in the present. On the other hand, it has brought about the formation, on this etch-washed plain, soils with a high saline, or even saline-sodic content,

Figg. 6-7 Examples of a soil profile in the oasis of Loiyangalani. (Photo: P. Magazzini).

Fig. 4 View of the landscape of the ancient lacustrine surface. (Photo: P. Magazzini).

Fig. 5 View of the basaltic hill landscape. (Photo: P. Magazzini).

due to the accumulation of previously weathered materials and subjected to secondary enrichment in very soluble salts and sodium, together with poor drainage conditions and with muddyy layers temporarily saturated with water during wet periods.

Although oases are typical of arid environments, low rainfall rate and constantly subjected to strong winds from two dominant directions, no remarkable aeolian erosion (and accumulation) events were observed concerning the current conditions, with the exception of small grass formations scattered on the lacustrine surface which seem to have porbably developed on sandy aeolian material.

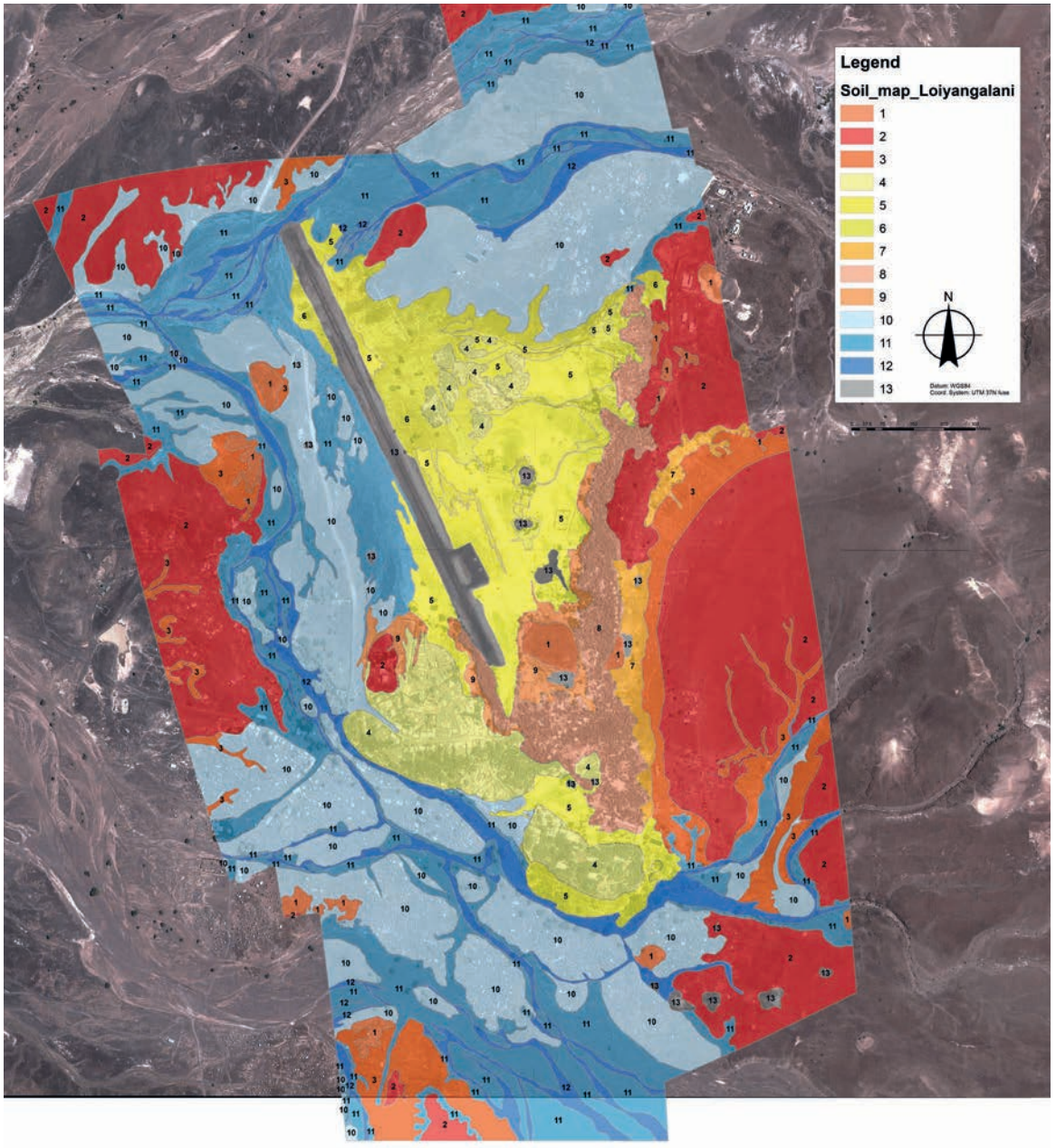
Soil formation processes

The most important local soil FORMATION PROCESSES (or pedogenetic processes) are certainly SALINIZATION and ALKALINIZATION, which affect most of the soils derived from the basaltic bedrock and the related colluvial and wash-out materials, while these phenomena are absent in soils of recent and very recent fluvial deposition. The latter are characterised instead by very thick sandy-gravelly to gravelly-pebbly material, with a very low water retention capacity. The absence of salinization in these soils is to be ascribed especially to high degree of hydraulic conductivity, the poor wheathering of the materials deposited or present on the edges of the current wadi, and the absence of capillary fringe. The potential aquifers under the wadi are too deep to have effects on the content of salts in the first metre of soil. Another pedogenetic process that seems to present itself below the saline-carbonate soils derived from the basaltic bedrock is connected to the concentration of calcium carbonates (CARBONATATION). Remains of organogenic shore deposits from the ancient paleolake are also present, which are particularly evident on the short erosion escarpments and are often locally used as building materials (small quarries).

Main soil typologies

The main soil types are grouped into three main morphological landscapes, since the distribution, typology and usage possibilities are clearly related to the following:

- Basaltic hills landscape.
- Ancient lacustrine deposits landscape.
- Alluvial terraces and current wadi landscape.



Unit: 1 *Rock Outcrop*					
Surface		ha:	5.17	Percentage:	1.42
Unit: 2 *Lithic Arenosols (Calcaric, Skeletic)*					
Surface		ha:	74.70	Percentage:	20.45
Unit: 3 *Skeletic Regosols (Calcaric)*					
Surface		ha:	19.95	Percentage:	5.46
Unit: 4 *Haplic Cambisols (Calcaric, Alcalic)*					
Total	area	ha:	16.83	Percentage:	4.61
Unit: 5 *Haplic Cambisols (Calcaric, Alcalic, Sodic)*					
Total	area	ha:	25.08	Percentage:	6.87
Unit: 6 *Calcaric Regosols (Alcalic, Sodic)*					
Total	area	ha:	14.00	Percentage:	3.83
Unit: 7 *Calcaric Cambisols (Sodic, Alcalic)*					
Total	area	ha:	4.15	Percentage:	1.14

Unit: 8 *Haplic Cambisols (Eutric, Calcaric)*					
Total	area	ha:	13.81	Percentage:	3.78
Unit: 9 *Calcaric Cambisols (sodic, Alcalic)*					
Total	area	ha:	4.71	Percentage:	1.12
Unit: 10 *Calcaric Fluvisols*					
Total	area	ha:	89.30	Percentage:	24.45
Unit: 11 *Calcaric Fluvisols (Sodic, Alcalic)*					
Total	area	ha:	64.18	Percentage:	17.57
Unit: 12 *Gravels and sandy deposits, no soils*					
Total	area	ha:	25.14	Percentage:	6.88
Unit: 13 *Urban areas and water bodies*					

Fig. 8 Soil map of the oasis of Loiyangalani, at a 1:10,000 scale. The numbers refer to the soil mapping units. (By: P. Magazzini).

Basaltic hills landscape

The basaltic hills are located mostly on the edge of the oasis and the soils of their surfaces are less developed, generally shallow, rich in skeleton and with a sandy texture and a low water retention capacity. Large areas with rocky outcrops are present, especially on the top of the elevations where the basaltic cupolas are found within the oasis (mapping unit 1). In these areas erosion is dominant, there is no vegetation nor soil, and therefore no possibility of development of natural vegetation, except for pioneering species.

Both outcrops of basaltic rock and their weathered products are present on the slopes (cartography unit 2), with a widespread presence of stoniness on surface and formation of very shallow soils, with an A-C-R or A-R sequence. Thickness varies between 20 and 40÷50 cm, with a loamy sand texture, rich in skeleton and extremely poor in clays. These soils are practically without structure, mostly loose and calcareous with a trend to accumulation of very soluble salts (chlorides, nitrates, sulfates) and alkalinisation (high ESP values). These soils belong to Lithic Arenosols (Calcaric, Skeletic) (FAO-WRB 2006). Herbaceous vegetation is absent, while some low thorny bushes are present, as well as rare specimens of Acacia Tortilis L.

At the base of the basaltic hills there is usually a short concave pediment (mapping unit 3), with accumulation of finer colluvial materials covering also the flat lacustrine surfaces below. These soils usually have a poor grass cover, and sparse formations of low thorny bushes with a widespread presence of acacia tortilis trees. The soils are shallow and rich in stoniness, with an A-C-R sequence and a thick loamy sand texture, calcareous materials and alkaline reaction, strong salinity and alkalinity. They have a low water capacity. They can, however, be enhanced with the introduction of tree species that are suitable to low humidity levels and shallow soils. These soils belong to the Skeletic Regosols (Calcaric) (FAO-WRB 2006). The following is a summarised infosheet of the physiographic and environmental features of the cartography units These soils usually have a poor grass cover, and sparse formations of low thorny bushes with a widespread presence of acacia tortilis trees.

The soils are shallow and rich in stoniness, with an A-C-R sequence and a thick loamy sand texture, calcareous materials and alkaline reaction, strong salinity and alkalinity. They have a low water capacity. They can, however, be enhanced with the introduction of tree species that are suitable to low humidity levels and shallow soils. These soils belong to the Skeletic Regosols (Calcaric) (FAO-WRB 2006). The following is a summarised infosheet of the physiographic and environmental features of the cartography units identified:

Mapping Unit: 1

Rock Outcrop

Surface ha: **5.17** Percentage: **1.42**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Basaltic cupolas: Dominant basaltic rock outcrops (with olivine and plagioclase), with scattered shallow and skeletal soils. No vegetation
SOILS
Non-soil areas (pedogenesis absent)
SOIL QUALITIES
None
SOIL LIMITATIONS
Diffuse rock outcrops
SOIL POTENTIALS
No possibility of a vegetation layer development

Mapping Unit: 2

Lithic Arenosols (Calcaric, Skeletic)

Surface ha: **74.70** Percentage: **20.45**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Basaltic hills: basaltic rocks (with olivine and plagioclase) outcropping on a shallow layer of soil. Vegetation almost completely absent, with the rare presence of sparse shrub-like trees (Acacia Tortilis L.)
SOILS
Very shallow soils A-C-R or A-R sequence, coarse texture, rich in coarse fragments. Of a brown humid colour, very friable, mostly loose, calcareous. Accumulation of very soluble salts and alkalinisation (high ESP value)
SOIL QUALITIES
None
SOIL LIMITATIONS
Low rooting depth, low level of water retention, deficit of nutrients
SOIL POTENTIALS
Only sparse grass formations. Urban trees. Needs emergency irrigation

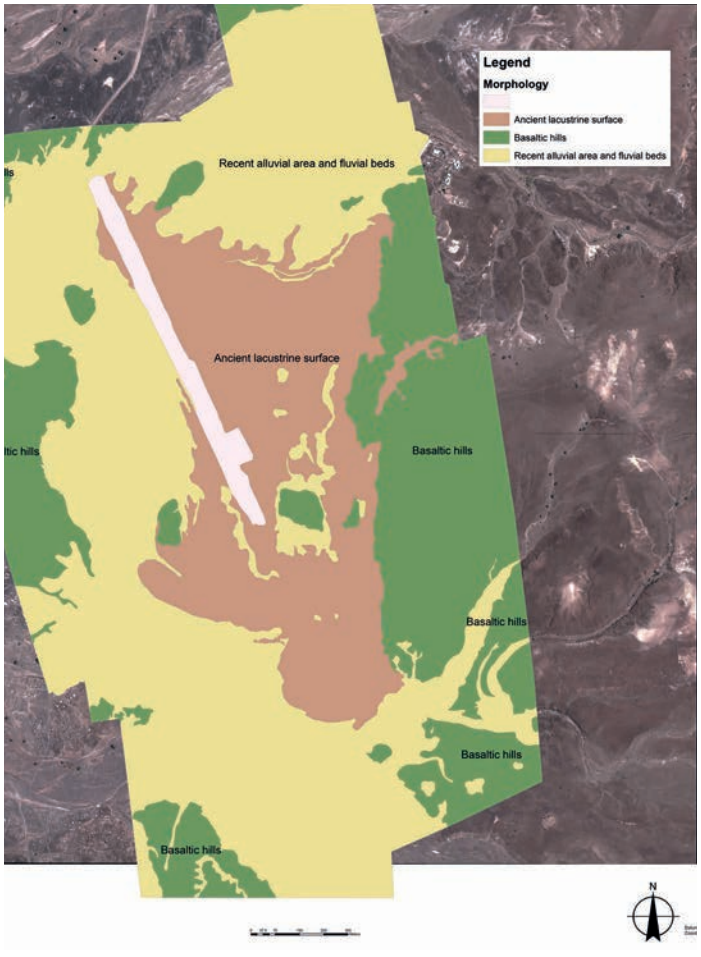
Mapping Unit: 3

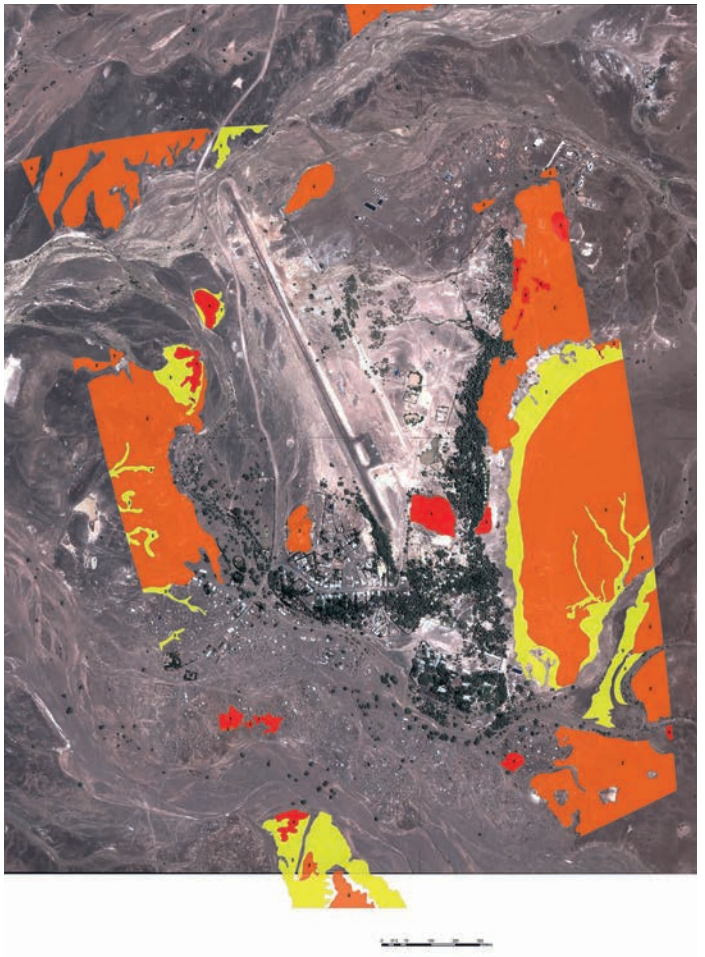
Skeletic Regosols (Calcaric)

Surface ha: **19.95** Percentage: **5.46**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Pediment; land subjected to colluvial deposition at the feet of the hills. Slope 10-15%. High surface stoniness. Areas with few trees (mostly Acacia Tortilis and bushes) and without grass.
SOILS
Dominant shallow soils, coarse textured, coarse fragments frequent, very friable and weakly structured, accumulation of soluble salts and a strong level of alkalinisation. (P6 2011)
SOIL QUALITIES
Moderately deep soil
SOIL LIMITATIONS
Erosion, stoniness, tendency to compaction
SOIL POTENTIALS
Suitable for diffusion of rustic bush and tree species, unsuitable for grazing due to shallow rooting depth

Figg. 9-10 View of the basaltic hills and their slopes. (Photos: P. Magazzini).
Fig. 11 Distribution of the three main landscapes identified in the oasis of Loiyangalani. (By: P. Magazzini).
Fig. 12 Distribution of the soils within the basaltic hills landscape. (By: P. Magazzini).





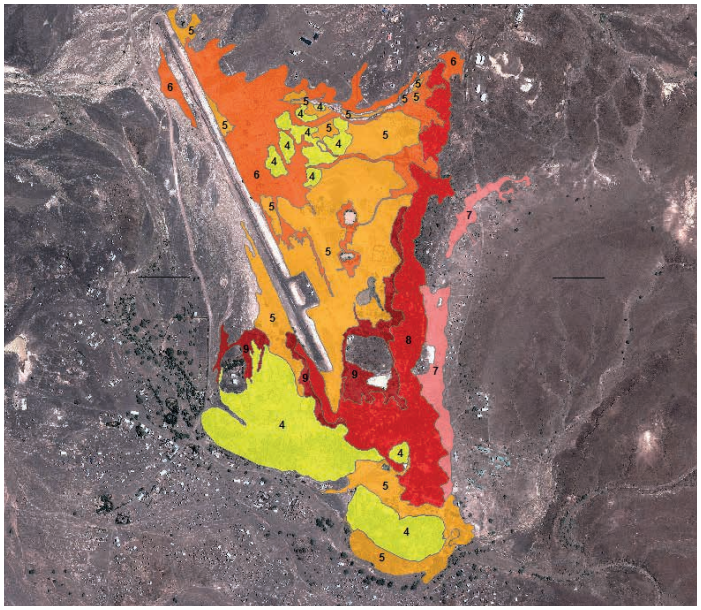


Fig. 13 Distribution of soils on ancient lacustrine surfaces. (By: P. Magazzini).

Fig. 14 View of the elevated lacustrine plain. (Photo: P. Magazzini).

Ancient lacustrine deposits landscape

The soils in this area developed on finer parent materials, such as loamy-sand, often buried under alluvial-colluvial depositions related to events which took place after the lacustrine phase.

They often have a larger horizon differenziation, are loamy textured, have a lesser content of coarse fragments nd superficial stoniness. On the other hand, in general a strong accumulation of soluble salts and a high level of alkalinity can be observed. They also present a low content in organic matter and fertility. These are soils, however, adequately managed, are suitable for supporting vegetation, both trees and grasses, for agricultural or landscape purposes.

Here degradation is more evident due to uncontrolled grazing; including the disappearing of the fragile grass layer, leaving these barren surfaces subject to both wind and water erosion. Actions are necessary in the entire area to oppose this process of erosion, with the adoption of fences and the introduction (through sowing or transplanting) of fast-spreading grasses that can oppose the actual trend of soil loss and salinization. The goal is to create a better environment to introduce new tree species. Another goal is to contribute with compost and materials of plant origin in order to increase the biomass of the soil and the protective effects that can create better edaphic conditions. The irrigation techniques, using water from nearby springs, must be carried out with the utmost care and attention in order to avoid the risk of increasing the content of very soluble salts and controlling the exchangeable sodium level.

In the middle of the oasis there are some low hills (mapping unit 4), characterised by shallow colluvium of coarse basaltic material on loamy lacustrine sediments lying over coarse deep sediments. Soils are moderately deep and silty-loamy textured with a few stones increasing in amount with depth. The sequence of the horizons is Az–Bw–C. The topsoil tends to be saline, even forming saline crusts, and the saline content decrease with depth. The high saturation of sodium, pH and ESP indicate the presence of a degrading alkalinisation process. The features of the soil indicate as well a clearly weak structure, weakned especially during flooding.This in addition to the reduced rooting penetration. The soils belong to the Haplic Cambisols (Calcaric, Alcalic) (FAO-WRB 2006)

Most of the lacustrine deposits landscape show a wide flat surface (mapping unit 5), with shallow alluvial-colluvial deposits. Part of the area which includes both the main village and the landing strip, is vegetated by groups of doum palms and big acacias with a dominance of barren soil and some grass formations, with a few discontinuous pillows. The soils developed on coarse alluvial-colluvial sediments material covering the finer loamy sandy sediments. The soils show an A-2Bw-2Cz sequence, with a high level of salinity in C horizon, and textures that span from loamy to sandy with depth. The reaction is alkaline with high exchangeable sodium levels in depth. These soils are suitable for trees and grass rehabilitation. The availability of waste water from springs may allow irrigation of the area, especially cultivating plants for fodder such as Vetiver. The soils

Fig. 15 View of the lacustrine plain with colluvial layers. (Photo: P. Magazzini).

belong to the Haplic Cambisols (Calcaric, Alcalic, Sodic) (FAO-WRB 2006).

North to the wide plain, is an alluvio-colluvial area, often quite deep (mapping unit 6). Trees are moderately widespread, with groups of doum palms in the depressions and a few acacias; while grass pillows are less developed or absent, with the exception of a few scattered grass pillows. The soils, with an A-AC- Ck sequence are less developed due to the the recent colluvial sediment deposition. They are moderately deep, with small basaltic stones that tends to diminish with depth. The texture is coarse, from sandy-loam to sandy, calcareous, with accumulation of carbonates in depth, high sodicity and moderately high salinity. Also in this case management problems are linked to the low levels of water retention, which reduce the agricultural production of these soils. The use of tree species requiring low amounts of water shoud give good results. The soils belong to Calcaric Regosols (Alcalic, Sodic) (FAO-WRB 2006).

Above the wide lacustrine plain is a brief escarpment (mapping unit 8), with a slope between 10 to 35%, largely covered with vegetation, dominated by the doum palms, but with the presence of other species (Sesbania sp., Moringa sp.). These trees have a partially anthropic origin and are more diffused in private (and fenced-in) properties. Most of the springs in the oasis are located on this escarpment, probably along a fault that shifted up the lacustrine surface. The soils are from medium to very deep, with a silty-loam texture and few coarse fragments. The horizon sequence is A–Bw–C, with the topsoil rich in roots extending in depth. The upper part contains carbonates, more than the underlying horizons. Deep horizons tend to have coarser, sandy textures (P2_2011 e P2_2015). Managment in this area must be orinted to conservation of soil and vegetation in order to mantain the tree cover and to protect slopes and springs. The soils belong to Haplic Cambisols (Eutric, Calcaric) (FAO-WRB 2006).

The lower part of the escarpments is a small pediment derived from erosion of lacustrine sediments (mapping unit 9), showing active erosion processes. Soils are relatively sloped areas with a shallow A horizon (P7_2011), somwhat absent in non-fenced areas, with moderately deep soils, non-calcareous on the surface, with an A-Bw-C horizon sequence and low salinity. A rehabilitation action can be done using fences and introducing artificial planting (through seeding or transplanting) of grassspecies that spread relatively quickly and which can counteract the current erosion trend and creating a better environment to introduce new tree species. The increase in biomass of the soil and its protective effect should bring back edaphic conditions such as those that are currently present on the above escarpment. The soils belong Calcaric Cambisols (Alcalic, Sodic) (WRB-FAO 2006).

Above the escarpment stay a flat area (mapping unit 7), over lacustrine sediments, but dislocated in height by the movements of the fault, characterised by modest quantities of coarse colluvial sediment originated by the dissolution of the above basaltic hills. This surface gradually merges into the pediment of the basaltic hills area. Trees are absent until the edge of the escarpment, where groups of doum palms are present, and there are some scattered grass pillows on sandy sediments, probably of aeolian origin. The soils show a moderate profile evolution, with A horizons on coarse colluvial sediments and sandier textures; the deeper horizons are finer, up to clay loam, with low salinity levels but a high sodium content. Fertile elements are generally absent, and organic and mineral fertilization must be added. The good water retention capacity and low salinity means a good suitability for trees cuiltivation, including those needing irrigation once, after the leaching of soluble salts that may appear on the superficial horizons. This is the area chosen for the irrigated palm garden and reforestation. The soils belong to Calcaric Cambisols (Sodic, Alcalic) (FAO-WRB 2006). The following is a summarised infosheet of the physiographic and environmental features of the various mapping units:

Mapping Unit: 4

Haplic Cambisols (Calcaric, Alcalic)

Total area ha: 16.83 Percentage: **4.61**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Slightly elevated lacustrine surfaces, with basaltic alluvio-colluvial sediments
Medium-low density tree groups and elements of degradation features with many doum palms. The Unit includes areas with urban expansion, fenced area and home gardens
SOILS
Dominant soils with a Az-Bw-C sequence, moderately deep on fine lacustrine sediments with superficial saline crusts. Medium texture (silt loam), alkaline, calcareous, moderately high salinity and sodicity (P3 2011)
SOIL QUALITIES
Good rooting depth and good water retention capacity
SOIL LIMITATIONS
Superficial degradationy. Salinity on surface, and medium-high alkalinity also in depth. Lack of nutrients.
SOIL POTENTIALS
Help the development with strong grass species, addition of compost and protection against erosion on slopes. Avoid surface irrigation systems

Mapping Unit: 5

Haplic Cambisols (Calcaric, Alcalic, Sodic)

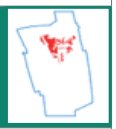
Total area ha: **25.08** Percentage: **6.87**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Flat lacustrine surface, eroded and with superficial colluvium of basaltic origin. Flat. rare vegetation, with sparse doum palms and acacias, discontinuous presence of grass pillows
SOILS
Dominant *soils with an Az-Bw-C sequence, moderately deep, on colluvial and lacustrine sediments. Medium (loam) to coarse (sandy loam) textures in the Bw horizon, alkaline, calcareous, low to high salinity in depth, high sodicity (P10 2015)*
SOIL QUALITIES
Good water retention capacity, low saline content on surface
SOIL LIMITATIONS
High sodicity, increasing salinity in depth
SOIL POTENTIALS
Good suitability for trees and grasses using moderate irrigation amount

Mapping Unit: 6

Calcaric Regosols (Alcalic, Sodic)

Total area ha: **14.00** Percentage: **3.83**



LANDFORM, PHYSIOGRAPHY AND LAND COVER
Lacustrine surface with coarse alluvio-colluvial basaltic materials. Flat morphology, with depressions. Groups of doum palms and acacias, grasses absent
SOILS
Shallow and slight developed soils with an A-AC-Ck sequence, coarse sandy loam and sandy textures, frequent to dominant coarse fragments, moderate alkaline reaction, very calcareous, moderately high salinity and sodicity below the A horizon (P9 2015)
SOIL QUALITIES
Moderate salinity
SOIL LIMITATIONS
Low water retention capacity, high sodicity
SOIL POTENTIALS
Use of tree species resistant to arid conditions, not suitable for grasses

Mapping Unit: 7

Calcaric Cambisols (Sodic, Alcalic)

Total area ha: **4.15** Percentage: **1.14**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Flat lacustrine surface elevated over the escarpment with frequent doum palms; few presence of colluvial material from the dissolution of the above basaltic hills. Trees absent until the edge of the escarpment, where doum palms are present, scarce grasses, with scattered grass pillows
SOILS
Deep to moderately deep soils with an A-2Bw-2C profile, moderately coarse (loamy sand) to moderately fine (clay loam) textures, alkaline, calcareous, low salinity, sometimes high salinity on topsoil, high sodicity (P1 and P3 2015)
SOIL QUALITIES
Moderatly rooting depth and moderate to good water retention capacity
SOIL LIMITATIONS
degradation on surface, crusts and compactness. Salinity sometimes high on surface, high alkalinity. Low nutrients content
SOIL POTENTIALS
Suitable for protected tree plantation and grasses species resistant to compactness of soil due to high levels of alkalinity. Possibility of irrigation, taking good care to carry out a correct leaching of salinity.

Mapping Unit: 8

Haplic Cambisols (Eutric, Calcaric)

Total area ha: **13.81** Percentage: **3.78**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Escarpment on coarse basaltic lacustrine and colluvial sediments. Multi-specific trees with good density and good level of development inside fenced home gardens. The Unit includes some urban settlements (Lodges and Resorts)
SOILS
Soils with A-Bw-C sequence, very deep (P2 2015), on colluvial sediments covering lacustrine sediments. Medium (silt loam) to sandy texture in depth, alkaline, salinity decreasing with depth, high sodicity on surface, calcareous on surface to slightly calcareous in depth
SOIL QUALITIES
Low salinity, low alkalinity in depth. Good water retention and rooting depth
SOIL LIMITATIONS
Lack of nutrients. Risk of degradation by erosion and deforestation
SOIL POTENTIALS
Suitable for grasses and tree species.
Emergency irrigation not necessary

Mapping Unit: 9

Calcaric Cambisols (sodic, Alcalic)

Total area ha: 4.71 Percentage: **1.12**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Pediment down to the lacustrine escarpment with doum palms; low tree density with sparse *doum palm and few acacias.*
SOILS
Moderately deep soils, weak structured with a discontinuous or absent A horizon, underlying a Bw horizon with a silty-loam texture, starting from from 20 to 30 cm and lacking in carbonates. Many roots (palms). The underlying BC horizon is coarse textured and a thickness of 50 cm thick, loose and with common alternated weathered coarse fragments, moderately calcareous. (P7 2011)
SOIL QUALITIES
Moderate salinity. Good water retention capacity and good rooting capacity
SOIL LIMITATIONS
Lack of nutrients. Evidence of degradation
SOIL POTENTIALS
Suitable for the development of grasses and shrubs. Introducing tree species at a later stage. Emergency irrigation possible.

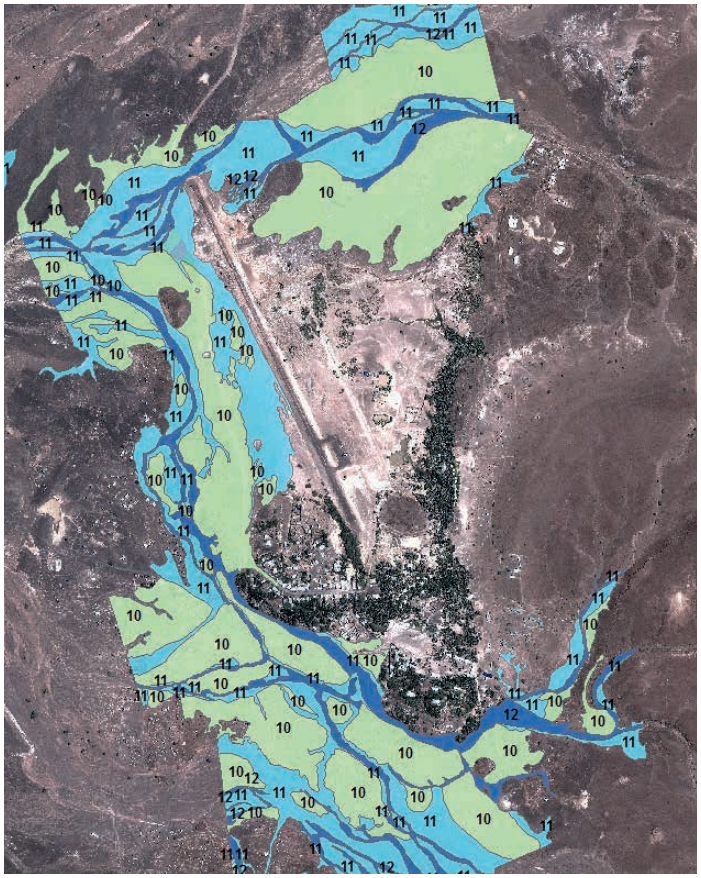


Fig. 18 Distribution of the soils on the alluvial terraces and on the main wadis. (By: P. Magazzini).

Alluvial terraces and current 'wadi' landscape (Laga)

The alluvial areas and the wadis, active only during the rainy season, are found to the south and north of the oasis, with slightly different manners of transportation and sedimentation, although the soils are not very differentiated from each other.

The loose deposits of this landscape have a very variable particle size distribution, depending on the energy flooding in the wadi. In general it can be said that in the wadi to the south of the oasis, which has a wider hydrological basin and more flooding energy, coarser material prevails, including pebbles and stones. In the wadi to the north of the oasis, the particle size distribution is dominated by finer materials, such as sand and gravel, with a lower presence of coarser elements. Finer material may also be identified in lenses which provide a relative increase in the water retention capacity, very important in these loose deposits with high permeability.

As for the wadis (mapping unit 12), considering the dynamic system subjected to seasonal changes, it is not possible to imagine a creation of a grass cover, with the exception of the natural scattered and seasonal grass piillows. This is easier on finer deposits where the energy of water flooding is low. Actually the grass formation are found on the edge of channels, especially where the water seep below the riverbeds.

At the side of the wadis two different elevated surfaces are present, defined as alluvial terraces slightly higher to the presentchannels of the wadi to the south (and south-west) of the oasis. These are areas are rarely subjected to flooding due to dispersion resulting from the multichanneled system. These loose deposits have coarse to very coarse particle size distribution, including pebbles and stones with decimetric dimensions. Lenses of finer material ared dominated by and silt. These deposits originated under weakly weathered oils, but very deep, which makes them suitable for tree rooting, limited only

Figg. 19-20 View of the first order alluvial terrace, to the left, and the second order, to the right (also highlighted the escarpment connecting the two terraces). (Photo: P. Magazzini).

by the presence of inordinately large macropores in the deposits and continuos bedrocks.

The first order terrace (mapping unit 11), issubject to occasional floodings, and 1 to 2 metres elevated above the present riverbed. It is situated in the alluvial area both to the north and south of the oasis. In general these areas are barren, eroded and stony areas with some doum palms and rare grass pillows used for grazing sheep and goats. The soils generally show a horizon sequence A–AC–2C1-3C2, with a different particle size distribution related to the various sedimentation phases. There is no evidence of a Bw horizon formation in place. They show a remarkable presence of a gross surface coarse fragments (including stones) and a finer (sandy) skeleton inside the profile. At the depth of one meter this soils present some humidity, and a water table three metres deep, even 3 months after the end of the rainy season. These features, despite the moderate risk of flooding, have determined the choice of this surface for the cultivation of Vetiver with the purpose of establishing grazing land and herbaceous formations which protect from water erosion (P4, P5, P6 and P7 2015). The soils belong to Calcaric Fluvisols (Alcalic, Sodic) (FAO-WRB 2006).

The second order terrace is elevated than the one (mapping unit 10), and mostly diffused in the southern section of the oasis, without the risk of flooding since it is 3 to 4 meters higher from the present riverbed. In the area to the east it shows evidences of colluvial material on the surface. As in previous Unit, it has a high stoniness on the surface and a slightly weathered profile, with a sequence of C horizons related to the depositional phases. The soils are generally barren, with few acacias and without grasses, which probably dissappeared due to grazing and anthropic pressure. On these surfaces, in fact, are located most of the dwellings of the Turkana groups, to the south, and the Samburu groups, to the north.

The soils are highly calcareous and have a generally low level of salinity and alkalinity. It is on these surfaces that the nursery for growing the plants necessary for the recovery of the oasis is located (P7 and P9 2015). The soils belong to Calcaric Fluvisols (FAO-WRB 2006). The following is a summarised infosheet of the physiographic and environmental features of the various cartography units:

Mapping Unit: 10

Calcaric Fluvisols

Total area ha: **89.30** Percentage: **24.45**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
Second order alluvial terrace, on alluvial deposits free of flooding, including recent urban development areas. Most of the areas show an almost total absence of vegetation, rare isolated acacias and some home gardens with a good trees density.
SOILS
Deep sandy soils, with large amounts of gravel and pebbles, profile A-AC-2C1-3C2, chalky (P7, P9 2015)
SOIL QUALITIES
No salininity and alkalinity. Good rooting depth, yet material is often quite thick
SOIL LIMITATIONS
Very low water retention capacity and high permeability. Lack of nutrients. High superficial stoniness
SOIL POTENTIALS
Increase productivity with compost and with diffusion of grasses. Diffusion of urban trees. Emergency irrigation recommended

Mapping Unit: 11

Calcaric Fluvisols (Sodic, Alcalic)

Total area ha: **64.18** Percentage: **17.57**

LANDFORM, PHYSIOGRAPHY AND LAND COVER
First order alluvial terrace, loose deposits of sand and gravel, often coarse with many pebbles. Recent and actual alluvial deposition, moderate presence of grasses and doum palm shrubs, sometimes subject to seasonal floods
SOILS
Deep sandy soils, with large amounts of gravel, often quite coarse, and pebbles, profile A-AC-2C1-3C2, calcareous (P4, P5, P6 and P7 2015)
SOIL QUALITIES
Good rooting depth, humidity within one meter from the surface
SOIL LIMITATIONS
Moderate salinity with depth, moderate alkalinity, low water retention capacity
SOIL POTENTIALS
Suitable for grasses species resistant to water erosion

Mapping Unit: 12

Gravels and sandy deposits, no soils

Total area ha: **25.14** Percentage: **6.88**

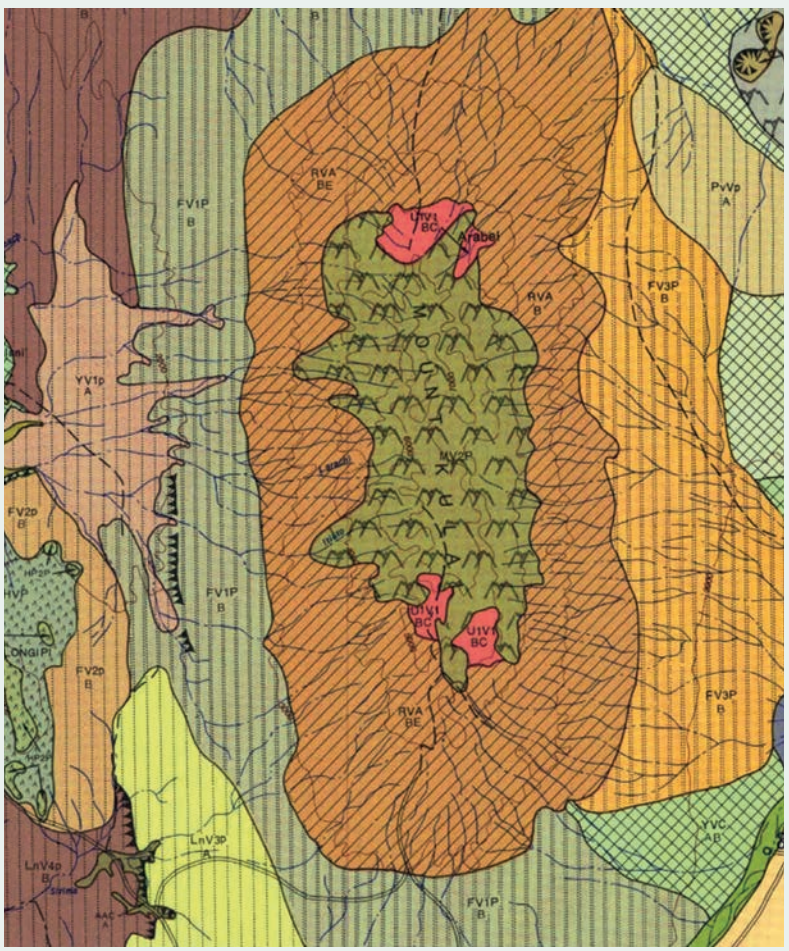
LANDFORM, PHYSIOGRAPHY AND LAND COVER
Seasonal waterbeds. Barren area with only scattered grass pillows
SOILS
Superficial layer of pebbles and gravel, no wheathering
SOIL QUALITIES
None
SOIL LIMITATIONS
Abundance of pebbles and gravel
SOIL POTENTIALS
Not suitable due to the risk of floods; in some casey the river banks may be strengthened by strong grasses diffusion (Vetiveria also)

RECONNAISSANCE SOIL MAP OF THE MOUNT KULAL-MARSABIT AREA

Piero Magazzini, Ugo Wolf

The existing information on the soils of the Loiyangalani are were obtained from the '*Reconnaissance Soil map of the Mount Kulal-Marsabit Area*' in a scale of 1:250.000, carried out in 1983 by the *Ministry of Agriculture, Kenya Soil Survey*.

Soil Reconnaissance Map of Loiyangalani area and surroundings (1983, 1:250.000). (By: P. Magazzini).



P – PLAINS

PId DISSECTED LACUSTRINE PLAINS
PIdx – Soil developed on sediments derived from various parent material
PIdxC - Complex of excessively drained to well drained, shallow to deep, dark brown to yellowish brown, loose to friable, strongly calcareous, moderately to strongly saline, moderately to strongly sodic, very stony and/or very gravelly, loamy sand to clay; in places stratified

A – FLOODPLAINS

AA – Soils developed on alluvial deposits
AA1 – Somewhat excessively drained, very deep, dark brown, loose, moderately calcareous, stratified, very stony and very gravelly, loamy sand (Calcaric Fluvisols, stony phase)

Y – PIEDMONT PLAINS

YV – Soils developed on colluvium and alluvium derived from various volcanic rocks
YV1p – Well drained, moderately deep to very deep, brown, very friable, strongly calcareous, slightly saline, moderately sodic, very stony to very gravelly, sandy clay loam, with an exceedingly stony surface (Calcic Yermosols, stone-mantic, stony, saline, sodic and partly petric or pisocalcic phase)

L - PLATEAUS

Lnv4p - Moderately well drained, moderately deep to very deep, dark reddish brown, friable, strongly calcareous, slightly saline, moderately sodic, clay loam to clay with an exceedingly boulder and/or exceedingly stony surface, in places very stony (Orthic Solonetz, boulder-mantic, saline and partly stony phase, and Orthic Solonchaks, boulder- mantic, sodic and partly stony phase)

F – FOOTSLOPES

FV – Soil developed on various volcanic rocks
FV1P – somewhat excessively drained to well drained, shallow to moderately deep, reddish brown to dark brown, very friable, strongly calcareous, slightly to moderately saline, slightly to strongly sodic, stony and very gravelly, sandy loam to sandy clay (Calcic Yermosols, stony saline, sodic and partly lithic or petric phase)

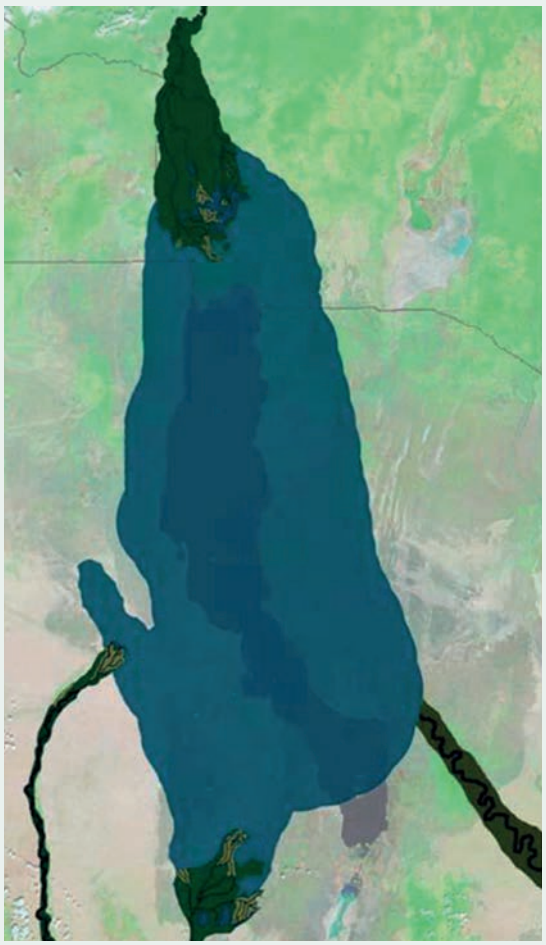
FV2P

well drained, moderately deep to deep, dark reddish brown, very friable, strongly calcareous, slightly to moderately sodic, very rocky clay, with an exceedling boulder surface, in places very stony and/or cracking (Haplic Yermosols, bolder-mantic, sodic and partly stony and/or petric phase, and Rock Outcrop)

RECENT GEO-MORPHOLOGICAL EVOLUTION OF TURKANA BASIN

Piero Magazzini, Ugo Wolf

Lake Turkana lies within the deep tectonic fault of the Rift Valley, at the place where it divides into the central and eastern Rift valleys. It is a deep tectonic rift which began forming 20 million years ago as a consequence of the sinking of vast territories between parallel faults. After the subsidience of this area, during different stages and up to relatively recent times, watercourses flowed into closed water basins that created great lakes, one of which is lake Turkana.
The Turkana Basin is a hydrographic and sedimentary system encompassing about 131,000km^2 of northern Kenya and southern Ethiopia. In its present configuration, the basin is hydrologically closed and dominated by alkaline Lake Turkana, with the Omo River as its primary source of water. As recently as the middle Holocene, it had connections to adjacent rift basins and an outlet to the Nile River. The present-day isolation of the Turkana Basin is in part due to the current water balance, but has at its roots the tectonic dynamics that have controlled accumulation and exposure of the sedimentary strata for which the basin is world-famous for paleontological and archaeological records.
Tectonic activity delineating the modern Turkana Basin began in Early Pliocene times, with subsidence related to the East Africa Rift System (EARS) that quickly took on a pattern of alternating half-graben trending north-south. Several significant pulses of tectonic activity are recorded in earliest Pleistocene times, and in a Middle Pleistocene phase of activity that culminated in the modern basinal configuration. During this most recent phase, subsidence along the basin axis has left structural blocks along the margin in topographically higher positions and subject to the erosion that has exposed Plio-Pleistocene sediments, fossils, and sites.
In the Early Pliocene, the Turkana Basin began to develop into a large integrated depositional system. Subsidence initiated accumulation along the existing drainage networks of an erosional landscape and quickly broadened to the complex of sub-basins that would dominate the region for the next four million years. The history of the basin through the Plio-Pleistocene can be traced as a succession of floodplain systems, during which fluvial deposition dominated, and lacustrine phases during which much of the basin was inundated. A major reorganization of the Turkana Basin landscape occurred about 4.1 Ma, when the first of the Plio-Pleistocene lakes, called Lonyumun Lake, developed. This lake system accumulated up to 120 m of sediment in some areas. This interval of time was also marked by the only basinally extensive volcanic episode of the Neogene, the basaltic complex of the Gombe Group.
These flood basalts produced a series of relatively thin flows that mantled much of the landscape and locally flowed into the lake. Subsidence of the basin did not keep pace with sediment influx, and the lacustrine landscape of Lonyumun Lake was replaced by an extensive fluvial floodplain, the Moiti Floodplain. The dominant element of the landscape through this interval was the ancestral



Paleogeographic reconstruction of the Lonyumun Lake (ca. 4.1 Ma), showing the extent of the lake as demonstrated by lacustrine facies, the Omo, Kerio and Turkwell deltas, and the presumed basin outlet in the southeast, leading to the Turkana River.

Omo River, meandering across the broad floodplain. The Moiti Floodplain was replaced over much of the depositional basin by a second lake phase termed the Lokochot Lake. The lake was relatively shallow, and appears to have been largely infilled rapidly. The Lokochot Lake was succeeded by a long-lived floodplain system.

Both Omo and Kerio river deposits show a wetter climate through part of this time. There are also two short lacustrine phases in this interval, the Waru and Kokiselei lakes. They are more geographically restricted than other lakes. Two significant changes began in the latter stages of the Floodplain, the development of the Hamar Uplift to the northeast, and the beginnings of formation of the shield volcano Mt. Kulal in the southeast. The uplift in the northeast tilted that quadrant of the basin, leading to formation of an angular unconformity-proximal to the uplift, which graded into an erosional disconformity. The growth of Mt. Kulal may have obstructed the basin outlet in the southeast, deflecting drainage progressively northward, but not entirely blocking it. The subsequent stage in basin evolution is the formation of the Lorenyang Lake, the longest lived of the Neogene lakes. This long time interval witnessed a complex shifting of landscape elements, with lake, delta, and fluvial components replacing each other in quick succession. Rapid subsidence in the northeast beginning with pelagic (deep lake) deposits and continuing with a fluctuating lake margin in the East. A short-lived return of a large-scale fluvial landscape occurred in the Chari Floodplain. This was followed by an enigmatic lacustrine phase. The cessation of Omo Group accumulation leaves a gap of half a million years in basin history before the known record of the modern lake. The most recent phase of sedimentary accumulation in the basin is related to the formation of Lake Turkana. Depositional patterns in the Turkana Group reflect two agents controlling sediment character: the major deltas and the lake itself. A major transgression of Lake Turkana began around 12,000 y BP, this phase is strongly dominated by lacustrine sedimentation, suggesting that mega-Lake Turkana, as an open-basin, freshwater system, was distinctly different from the earlier stages of Turkana Group history. The subsequent history of Lake Turkana is known primarily from the study of sediments beneath the modern lake, as the system shifted to the closed basin configuration of the present day, and lake levels have oscillated in response to short-term climatic variations. (source: *A geological history of the Turkana basin*, Craig S. Feibel, 2011)

Reconstruction of paleogeography at Moiti Tuff times (3.97 Ma) as demonstrated by the distribution of both channel and floodplain facies of the ancestral Omo River, as well as deltaic and paludal (marsh) facies preserved in the southwest. (By: P. Magazzini).

Doum Palm grove and the village. (Photo: L. Vallerini)

Vegetation in the area of Turkana and plant associations in the Oasis of Loiyangalani

Acaciae and Palm groves in Loiyangalani. (Photo: L. Vallerini).

Fig. 1 Type of structure of vegetation (Source: Henk Beentje, Kenya trees, shrubs and lianas, 1990 c.a.). (Source: Henk Beentje, Kenya trees, shrubs and lianas, 1990 c.a.).

Lorenzo Vallerini

Vegetation in Marsabit County

The main types of vegetation present in Marsabit County are apparently well related to the weather, the soil substratum and the geomorphology that characterise its various areas and can be classified into nine categories: the vegetation of the arid or sterile lands (*barrenland*), annual herbaceous species, dwarf shrubs, bushes, scrub/brush (*bushland*), perennial herbaceous species, evergreen or semi-deciduous scrub/bush, and evergreen forest.

Vegetation in the arid/sterile areas or *barrenlands* is located mostly in the desert of Chalbi. The accumulation of salts deposited in the soil due to the high level of evaporation, of seasonal floods and of the flow through perennial springs, generally inhibit the growth of plants. In fact the desert of Chalbi is a desert in the full sense of the word, characterised by the scarcity of vegetation.

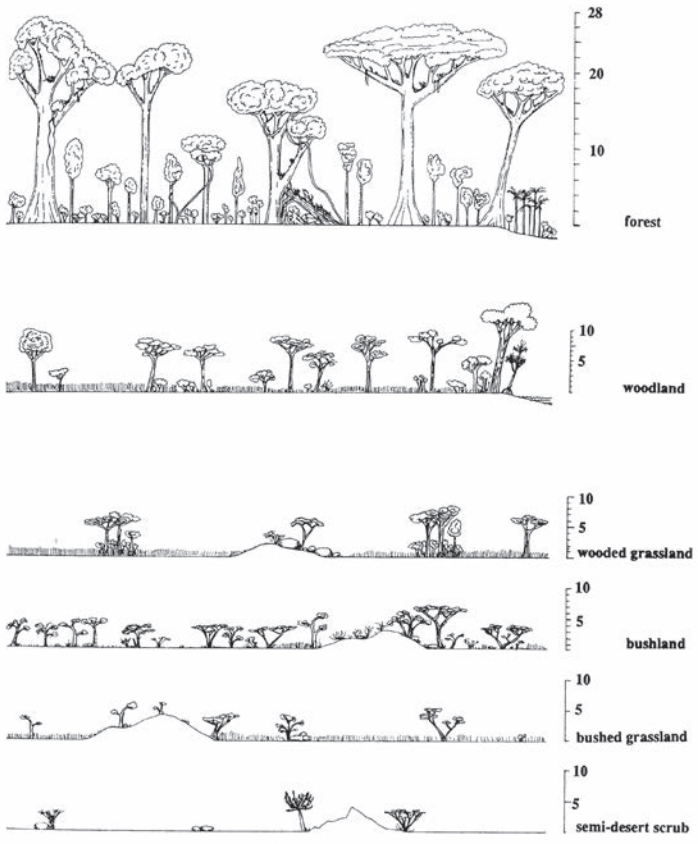
Annual herbaceous species are the most widespread type of vegetation in the County and is characteristic of the areas located under an altitude of 1,000 metres above sea-level. This type of vegetation is usually found in shallow, underdeveloped, stony and/or clayey soils, often in areas characterised by layers stratified over lava deposits where, mixing with the vegetation of the *barrenlands,* it shares the dryer climate areas in the District.

Dwarf shrubs are the second most widespread type of vegetation and are mostly represented by small shrubs under one metre in height (the dominant species are *Duosperma eremophillum* and *Indigofera spinosa*).

The third most widespread type of vegetation are the mainly deciduous shrubs under six metres high, who live in association with annual grassland and other herbaceous plants: the most widespread shrub is the *Acacia reficiens.*

This vegetation is typical of clayey soils of volcanic origin at higher altitudes in the main mountainous areas and, at lower altitudes, of sandy and clayey/alluvial soils.

Thus the main and more widespread vegetation consists of annual herbaceous species, low dwarf and slightly higher shrubs, which, together with the vegetation of the *barrenlands*, occupy the most arid areas in the District, while the more 'humid' vegetation is less widespread and found only at higher altitudes following some watercourse. This category of vegetation includes the scrub/bush (*bushland),* evergreen herbaceous species, evergreen or semi-deciduous scrub/bush and the evergreen forest.



CANOPY COVERAGE OF VARIOUS TYPES OF HABITAT ALONG A LINE 1 METER WIDE

While the *bush,* which is a mix of deciduous trees and shrubs, grows on the rocky slopes of some mountain areas (Nyiru, Ol Doinyo Mara and Ndoto) and on the higher elevations of Mount Kulal, evergreen herbaceous species and evergreen or semi-deciduous scrub/bush are found on the highest elevations which have a milder weather with more rainfall, whereas the evergreen forest is found exclusively on the mountain peaks which have large amounts of rainfall, mist and a low degree of evaporation.

Vegetation in the area of Loiyangalani and Lake Turkana

The composition of the vegetation in the area of Loiyangalani, from its eastern limits to the shores of lake Turkana, is unexpectedly rich and varied, considering the nature of the soil, its orientation and exposure. The area goes from the oasis itself, with the presence of many springs and a shallow stratum of fertile soil that has allowed the growth of a complex plant vegetation system, to the areas bordering the oasis which present less fertile soils and a lack of water which have restricted, together with human activities, the possibility of a denser vegetation, and finally to the areas near the lake with saline soils where only some herbaceous species and bushes grow which have adapted to the extreme conditions of the ground.

The boundaries and articulations of the various plant associations are not as clearly defined, except in the oasis itself and in the areas marked by seasonal watercourses, and these mix and blend with each other depending on the various concentrations of salts in the soil, of their more or less intensive use for grazing purposes, and of the availability of water.

The plant associations identified in the area of Loiyangalani and on the shores of lake Turkana are however classifiable as[1]:

- Shrub-grassland associations *(vegetation type* 7) consisting in dwarf and tall bushes and shrubs in various combinations with grassland and annual or evergreen herbaceous species distributed according to three different typologies of plant associations:
  - *Commiphora- Acacia* shrubs- herbaceous species with dwarf bushes and annual and evergreen herbaceous species;
  - *Acacia mellifera/ Acacia reficiens*, shrubs-grassland with dwarf bushes, annual herbaceous species and grass;
  - Shrub-grassland with a variety of species of *Acacia* and *Capparaceae.*
- Dwarf shrub-grassland associations (*vegetation type* 8) which consist of mostly non-uniform grasslands with dwarf shrubs scattered or in groups; these associations are very common in the area of Loiyangalani
- Barrenland associations (*vegetation type* 9), typical of areas with very poor or sterile soils in which vegetation is scarce and often found in strips on those parts of the ground that are more humid (the concentration of vegetation increases with the amount of hydric availability). During years with particularly little rainfall, many of these areas appear as deserts, whereas in the presence of rain they become green and include large grasslands made up of annual species; these associations, very typical of the area of North Horr and Ileret, include mainly the following species:
  - Along the drainage strips or torrents dwarf shrubs and mostly scarce grassland, with a covering of the surface inferior to 2%, which changes in relation to the quantity of water available:
  - Annual grasslands with the presence of a dominant species
- Shrubland to grassland on saline soils associations *(vegetation type* 12) found along the strips of land bordering the desert of Chalbi or along the shores of lake Turkana consist of non-uniform grassland with scatterings of individual or groups of dwarf shrubs;
- The associations typical of the Oasis of Loiyangalani, where many springs are present, are dominated by palm groves of the species *Hyphaene compressa* or Doum palm characterised, in the areas not subjected to intense grazing, by a sort of undergrowth of various species of bushes with open areas covered by grasslands made of annual herbaceous species such as *Aristida mutabilis* and *Aristida adscensionis,* together with *Eneopogon* and *Cenchurs*. The palm grove strip things out in the areas without water, where the species that characterise the more arid barrenlands are found, whereas in the areas with seasonal streams (Wadi or 'Laga' in the local language) and of the natural drainage systems, the dominant tree species found is the *Acacia tortilis,* with the presence as well of *Delonix elata.*

Thus, the area of Loiyangalani and its surroundings, with the exception of the oasis itself with its palm groves, is characterised mostly by the presence of deciduous bushes and dwarf bushes, with vast zones of barrenlands in which vegetation is even scarcer. The most

Fig. 2 Working at the survey of plants. (Photo: L. Vallerini).

Fig. 3 Specimen of Acacia tortilis in the Palm grove. (Photo: L. Vallerini).

common species are the bushes of *Indigofera spinosa, Duosperma eremophillum, Sericocomopsis hildebrandtii, Acacia reficiens, Acacia mellifera* and *Commiphora africana*, whereas the main trees present in the area are *Acacia tortilis* and *Delonix elata.*

The layer of herbaceous species, scarcely scattered during the dry season and more continuous during the rainy season, is composed mostly of annual herbaceous species such as *Aristida mutabilis* and *Aristida adscensionis* and, along the lake, by salt-tolerant herbaceous species, the most common of which is *Sporobolus spicatus*.

Vegetation surveys in the oasis and in the urban area of Loiyangalani

The vegetation surveys in the oasis and in the urban area of Loiyangalani were carried out through sampling in some sections but were not systematic enough for a proper survey and classification of the various associations found in the area.

The work carried out by the local CBO[2] *Nanyori Group*, itself supported (2004-2006) by the Monegasque Association *Wings for Earth - Des Ailes pour la Terre*[3], which resulted in the establishment of a Nursery for the cultivation of local plants to be used for the reforestation project known as *Nanyori Green Belt* and the planting of various species of bushes and trees, was certainly of great help in beginning to understand both the existing plant typologies as well as the problems present in the area and the adopted solutions.

The members of the *Nanyori Group* supported the entire action and work of the research group.

The vegetation surveys of 2008, later perfected in 2011, were carried out at the old nursery of the *Nanyori Group* and in some of the surrounding areas, including the settlement-village of the Turkanas, where some of the main plant species, both in their natural habitat and planted by the CBO were surveyed, as well as along the main branch of the oasis where the natural springs are found, in the areas of El Molo Camp and the Oasis Lodge (both enclosed areas which preserve the original vegetation of the oasis), at the settlement-village of the Samburu and the areas near the airstrip, at the Dispensary of Loiyangalani, run by the Italian Sisters, where a survey of the vegetation was undertaken in the areas recovered through the planting of numerous species and thanks to the reconstitution of the fertility of the soil with the help of manure and, finally, in an area of urban expansion.

Direct vegetation surveys were carried out also outside the limits of the oasis of Loiyangalani, both at the settlement-village of the El Molo tribe to the north of Loiyangalani, along the shores of lake Turkana, and subsequently in the oasis of Ngbole or *Mountain of the Moon,* and in the surrounding springs, to the north in the direction of Koobi Fora, which included a verification of the plant associations that are typical of those areas.

As previously mentioned, the experiences obtained by the Nanyori Group at the old Nursery was very important both in terms of recognising the plant associations in the oasis and of identifying the plants that can be used for reconstructing and expanding certain areas of the oasis.

In fact the Nanyori Group had set a series of main objectives for the

management of the Nursery and the planting of trees and bushes in the oasis, such as:

- Growing plants that are capable of resisting to the terrible conditions of the soil, the lack of water and the strong winds;
- Growing plants that can represent a source of nourishment (fruit, vegetables, etc.) for the population (the main sources of food are fish from the lake and milk from goats and sheep, and occasionally camels);
- Growing plants that can serve as fodder for livestock;
- Growing plants which can produce exportable products, such as gum Arabic (*Acacia Seya*l) or the leaves of *Aloe vera*, or other plants used for medicinal or cosmetology products.

Many of the plantations did not produce satisfactory results, probably due to the methods of planting and watering (too much water in sodium-rich soils), but many others, sometimes unexpectedly, took root, developed and grew with vitality. It must be underlined as well that for every single planted specimen, systems were set for their protection from the wind and livestock, with the use of intertwined stakes, some of which made from thorny species. The plantings were however numerous and were distributed over many areas, especially in the settlements surrounding the oasis itself, that is mostly outside the palm grove.

The plants observed in the Nursery were:

- *Acacia brevispica* harms.– bush of mid-to large dimensions or small tree, h 2÷5 m / took root remarkably well in Loiyangalani;
- *Acacia senegal* (l.) willd. – deciduous bush/tree, h 15 m max / took root remarkably well in Loiyangalani - gum Arabic, sudan gum Arabic, three-thorned acacia, kikwata, mgunga;
- *Azadirachta indica* a. juss. – medium sized tree, usually evergreen, h 15 m, 30 max / took root well in Loiyangalani - Persian lilac, neem tree, bastard tree, bread tree, mwarubaini, mwarubaini kamili, mkilifi;
- *Balanites aegyptiaca* (l.) del. – many-branched and thorny bush/tree, h 10 m max / took root remarkably well in Loiyangalani - desert date, Egyptian myrobalan, soap berry tree, simple thorned torch tree, mjunju, mwambangoma;
- *Delonix regia* (hook.) raf. – remarkably large tree, 10÷15 m, 18 max. / took root remarkably well in Loiyangalani - flamboyant flame tree, gold mohar tree, flame tree, peacock flower, mjohoro, mkakaya;
- *Moringa stenopetala* (bak.) cuf. – medium-sized tree, h 6÷12 m / took root remarkably well in Loiyangalani, cabbage tree;
- *Parkinsonia aculeata* (l.) – small, fast-growing tree, h 4÷10 m max / medium to low adaptability to conditions in Loiyangalani - thorny broom, Jerusalem thorn, wonder tree, horsebean, mkeketa;
- *Salvadora persica* (l.) – many-branched evergreen tree, 6÷7 m / took root remarkably well in Loiyangalani - toothbrush tree, mustard tree, musuake, msuake, mswaki;
- *Tamarindus indica* l. – large evergreen tree, up to 30 m max / medium adaptability to conditions in Loiyangalani - tamarindo, tamarind tree, indian date, madeira mahogany, msisi, mkwaju.

Other plants cultivated at the Nursery in Loiyangalani, such as *Senna obtusifolia* (*Emany* in the language of the Turkana, low bush) or *Ricinus communis* (or castor-oil plant, a low ligneous herb), were used in the area but either did not give good results, or are in the process of taking root or of growing. Others, such as the common melon (the variety is unknown) and the watermelon, have given good results even on difficult soils when abundantly watered.

Within the inhabited area the plantings have given satisfying results and, thanks to the initiative of some of the inhabitants, there are some cultivated areas (mostly sorghum) and in some small sections with stagnant water there are also rushes and *Tiphae*.

Among the main species found are the following: *Azadirachta indica* or neem tree, *Moringa stenopetala*, *Tamarindus indica*, *Salvadora persica*, *Parkinsonia aculeata*, *Acacia Senegal, Ziziphus mucronata* or Buffalo-thorn.

In the sections settled by the Turkana the dominant species is one of the most common types of acacia in the area, *Acacia tortilis* or Umbrella thorn.

The 'palm grove' itself features mostly *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm, a palm which comes from the valley of the Nile in north-east Africa and which reaches a height of 18 m. Under the foliage of the palms, in the sections not yet devastated by wild grazing (that is fenced in), a sort of undergrowth exists, rich in local plant species.

Unfortunately, in the eroded areas, or which have lost the autochthonous brush as a result of uncontrolled grazing, an invasive imported plant has become widespread, *Prosopis juliflora* or 'mesquite', a thorny bush native to Mexico and Central America (*Eterai* in

Fig. 4 'Natural' association between Acacia and Salvadora and the work group. (Photo: L. Vallerini).

Fig. 5 Cultivation of plants in the old Nursery of the Nanyori Group. (Photo: L. Vallerini).

the language of the Turkana) which can reach a height of 15 m. This plant, which grows remarkably fast is cultivated in tropical areas and grows well in arid zones as well, in poor and saline soils and at altitudes as high up as 1,500 metres above sea-level. In the presence of water it becomes invasive. The fruits, which a long sweet pods and the leaves are eaten by livestock, but produce negative effects, including death, caused occasionally by thorns which are difficult or even impossible to digest.

The bush, a sort of plant 'alien', is becoming widespread in an alarming way in the area of Loiyangalani and can become a serious environmental problem with risks for the health of both humans and animals. In other areas of the region, such as the district of Baringo, along lake Turkana (from the airplane wide green strips can be seen along the shores and in the lowlands) and in the district of Tana River this plant has colonised wide areas and supplanted the local vegetation, endangering the wild fauna as well. If a solution is not found for its elimination (it is difficult to uproot and when cut grows back stronger and faster than before) it can contribute to the decay of the oasis.

Within the oasis itself, in areas with more structured buildings, some specimens of palm trees were observed (*Phoenix dactylifera, Phoenix canariensis* and *Phoenix reclinata* or Wild Date Palm) which grow higher than 10 m. These are not indigenous plants, yet seem to adapt well to the difficult conditions of the soil, and have been widely used also for dietary purposes (Wild Date Palm and Date Palm), as long as they are adequately pollinated from male date palms.

Also inside the oasis, in the clearings or on the bordering sections exposed to light and with access to water (or after the rains) there are 'fields' characterised by the presence of annual herbaceous species, especially *Aristida adscensionis* and *Aristida mutabilis* and, to a lesser extent, to *Eneopogon* and *Cencrus*. Along the lake or in more saline soils, instead, grasslands are found with the dominant presence of a species that tolerates salts very well, *Sporobolus spicatus*.

This layer of herbaceous species constitutes the ideal 'natural' situation for the interior areas of the oasis, and would be as well for its bordering areas, but the excessive presence of grazing livestock often produces its progressive disappearance, with the consequent reduction of that thin stratum of more or less fertile soil which constitutes the basis of the entire ecosystem, and which during the rainy season is additionally reduced by phenomena of superficial erosion.

As has traditionally been the case in the development of human settlements, the progressive anthropic pressure reduces natural resources until reaching a break in the pre-established balances which, in the case of an oasis, are particularly fragile. The only possible alternative is an intervention intended to invert the trend, without however making use of apparently easy short-cuts (such as the introduction of 'alien' plant species, or technological methods that are not compatible with local knowledge, etc.), but rather aiming at reconstructing as much as possible the natural cycles with the participation of the local population.

The area of El Molo Camp-Lodge is one of the zones which maintains intact the original vegetation structure of the oasis system. It is part of a fenced-in private property used for tourism and hospital-

Fig. 9 Garden at the Dispensary of the Italian Sisters in Loiyangalani. (Photo: L. Vallerini).

Fig. 6 Growth of non-local invasive weeds: Prosopis juliflora. (Photo: L. Vallerini).

Fig. 7 Herbaceous Sporobulus spicatus along the rivers of the lake. (Photo: L. Vallerini).

Fig. 8 Doum palms at Oasis of the Moon or Ngobole. (Photo: L. Vallerini).

ity purposes (actually in a state of semi-abandonment, but undergoing some early rehabilitation intervention processes) which protected it from the wild grazing practices which characterise many other sections of the oasis; this has allowed the vegetation of the oasis to develop almost undisturbed, except for the introduction of certain 'non-indigenous' plants which have been imported, or which are common in other parts of Kenya.

Among the species observed, the most dominant is the so-called *Loiyangalani Tree*, much used as building material, and which has almost disappeared outside the fenced-in areas. It is, however, very common in many other parts of Kenya. Its scientific name is *Sesbania sesban (l.)* merr., (S. aegyptica), also known as *River bean*, a small deciduous tree which is normally found in areas where water is abundant, especially on the shores of lakes or even inside the water itself, but which also withstands acid or saline soils.

Another important species observed, very widespread throughout Kenya, is the *Ficus sycomorus l., Wild Fig, Sycamore, Mukuyu, Mkuyu, Chivuzi,* or Echoke[4] in the language of the Turkana, which belongs to the family of the Moraceae. It is a large deciduous tree which grows as high as 21 m, in areas near rivers or with an abundance of water, but also in the bushland or in woods of more droughty areas.

Other species observed were *Salvadora persica,* whose features have already been referred to, and which is very common in the entire Turkana area, as well as numerous bushes that have not yet been classified.

Another species observed, probably imported from other parts of

Fig. 10 Grazing and erosion of the topsoil. (Photo: L. Vallerini).

Fig. 11 Acacia and Commiphora in the more arid lands. (Photo: L. Vallerini).

Fig. 12 Sequence of degraded palm groves on the edges of the oasis. (Photo: L. Vallerini).

Fig. 13 Water erosion inside the Oasis. (Photo: L. Vallerini).

Kenya, is a medium-large tree of the Albizia family, possibly *Albizia schimperiana Oliv.*, which can grow as high as 24 m, and is found both in lowland woods or dryer woodlands.

The remaining areas of El Molo Camp Lodge are mostly covered in the typical 'palm grove', mostly consisting of *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm, common throughout the oasis. Various springs and water wholes are placed along a single water outlfow which continues outside the Camp-Lodge: in an area with a widespread water surfacing a thick grove of *Pragmites* reeds has developed.

As mentioned before, two other 'highly cultivated' areas, almost garden-like and enclosed by fences, concern the Oasis Lodge and the Loiyangalani Dispensary, run by Italian nuns.

In both cases, as has been confirmed by the owner of the Oasis Lodge and by the nuns, before carrying out any intervention with new plantings, the fertility of the soil was enhanced with a succession of strata of manure (especially from goats), which gave good results. In both areas the pre-existing vegetation, typical of the associations in the oasis (doum palm and/or Acacias), was complemented with new trees and bushes, both local and imported; a fundamental role in the success of these interventions was played, as in the case of the El Molo Camp-Lodge, by the complete absence of any sort of animal grazing.

The vegetation survey included numerous species, among which Sansevieria, Bounganvillea, Hibiscus, some Euphorbia, Oleanders,

Fig. 14 A view inside the Oasis at the Palm Shade Lodge. (Photo: L. Vallerini).

dwarf palms, Yucca, Aloe, Mimosaceae, etc. At the Oasis Lodge several specimen of *Pulmeria alba* were found, also known as Frangipani, they are small, evergreen and succulent tree-bushes, with a maximum height of 5 m and beautiful white flowers (another variety has pink flowers), as well as some specimens of *Leucaena leucocephala,* an evergreen tree-bush which grows to a height between 5 and 20 metres, of the family of the Mimosaceae, characterised by wide white flowerings and long pod-like fruits which are harvested in groups.

In the areas near the landing strip, on the one hand, and on the outer borders of the oasis, on the other, there are wide barren strips which alternate, in the presence of water, with herbaceous vegetation which is deemed to be composed mostly of *Aristida adscensionis* and *Aristida mutabilis* and by small, to medium-large groups of doum palms and isolated Acacias.

The village of the Samburu is, in fact, located in a desolate piece of land, yet the presence nearby of more or less organised water sources, as well as of some grazing areas and the edge of the oasis, give this ethnic group some opportunities for survival.

Unfortunately erosion due to wind and weather, together with the excessive grazing, have reduced the available vegetation to the minimum, and the oasis itself, in this outmost strip, seems to be remarkably damaged.

Some specimens of Acacia and Salvadora have been planted in the village itself, as well as some Neem trees, with relative success, due probably to the lack of care given to the plants.

However, the natural 'marriage' between Acacia and Salvadora trees, which has also been observed in other areas, even far from the oasis, must be underlined. It could be an indication of natural vegetation associations to be taken advantage of in reforestation interventions.

Returning toward the central section of the oasis, beyond the landing strip, is an area characterised by an alternation of strips of Doum palm and acacia woodland with wide expanses of very degraded grazing land. Many new trees in good condition were planted near the more inhabited areas, yet the uncontrolled expansion of the invasive *Prosopis juliflora* continues.

In the almost barren built areas outside the oasis, among the shacks-dwellings and with the purpose of bettering the dwelling conditions, specimens of the Neem tree, Oleanders, Tamarinds, Salvadora, Acacia and *Jerusalem thorn* were planted, all of which are growing adequately.

Surveys carried out outside of Loiyangalani, to the north, included the area of the settlements-villages of the El Molo ethnic group along the shores of lake Turkana, the Oasis of Ngbole or *Mountain of the Moon,* and the surrounding springs, as well as the Ethno-Anthropology Museum established with the support of Italian cooperation, in which, among the exhibition panels regarding the natural ecosystems and cultures of the area of Turkana, there is one on the most important plants and annual flowering bushes.

The vegetation in the areas visited is very scarce, except for the Oasis of Ngbole where the same plant associations are found as in the Oasis of Loiyangalani, with the dominant presence of the Doum palm.

Along the path that connects the villages many grazing areas were observed with the presence of numerous domestic animals, all in an advanced state of degradation. In the village of El Molo, in a section overlooking lake Turkana, grassland was observed with the presence of *Sporobolus spicatus,* a herbaceous species that is well-adapted to saline soils; even in this case, though, the relative pressure exerted by

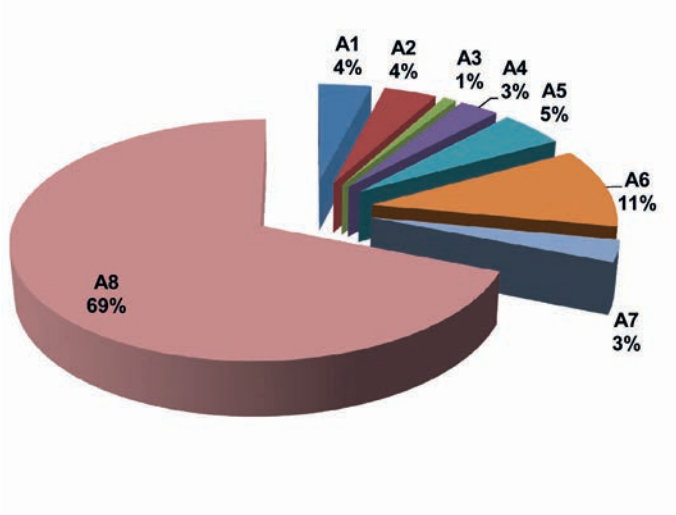


Fig. 15 Diagram of Surface Plant Associations. (By: L. Vallerini).

the grazing of goats is damaging the layer of grass. In that same village a few Doum palms and Acacias were planted, with little success.
With the use of an airplane, finally, a series of surveys were carried out at distances of 120-150 km from Loiyangalani, in the area north-east of lake Turkana, in Koobi Fora at the Sibiloi National Park; no specific vegetation was observed, except for the presence, very widespread in the area, of *Adenium obesum,* the so-called 'Desert Rose' or 'Bottle Tree'. The plant associations observed during the journeys in off-road vehicles are all the same that are typical to the eastern shores of the lake, already described.

Plant associations and their evolution

As a result of the surveys carried out, both at the ground level and interpreting the photographs obtained from the aerial surveys, the information gathered in Loiyangalani directly from the local population and from the CBO *Nanyori Group*, as well as from the consultations and assessment of the scientific documentation obtained during the missions, it was possible to draft a series of maps including a classification of plant associations:
In the 'Vegetation Map' (scale abt 1/3.500) weintended especially to identify and circumscribe issues, as well as to understand the qualities and potentials of the oasis ecosystem and its surroundings in order to pinpoint possible intervention actions to recover the balance of the vegetation system.
From this classification it was possible to deduce the areas regarding each association in relation to the entire area of Loiyangalani which was the object of analysis and research.
Numbers speak by themselves.

The palm groves and areas with the presence of acacia, which occupy roughly 17% of the total surface, are invaded by Prosopis, urban growth or intensive grazing for a total of 13%, which means that only 4% of the total may still be considered as a healthy palm grove ecosystem with the presence of all the plants of which it is composed.
The palm grove is in a process of decay and in a phase of reduction!
14% of the considered area is still characterised by plant associations in evolution, although typical of arid and semi-arid zones, with some residual herbaceous species for grazing.
69% of the area is characterised by the presence of decaying vegetation or without vegetation altogether.

Loiyangalani - Surface Map Plant Associations

UNIT	DESCRIPTION	SURFACE M2.	%
A1.	Palm grove plant associations with a prevalence of Hyphaene compressa (H.multiformis, H. thebaica) or Doum palm with some presence of Prosopis juliflora	171,370	4%
A2.	Palm grove plant associations characterised by a scarce presence of Hyphaene compressa (H.multiformis, H. thebaica) or Doum palm, Acacia tortilis or Umbrella or White thorn and other bush species introduced by man, especially Prosopis juliflora, which have become widely spread	145,463	4%
A3.	Plant associations with a prevalence of Acacia tortilis or Umbrella or White thorn and Acacia ssp. with an important and increasing presence of Prosopis juliflora	27,201	1%
A4.	Plant associations with the presence of scattered groups of Hyphaene compressa (H.multiformis, H. thebaica) or Doum palm, dwarf bushes annual and evergreen herbaceous species	130,329	3%
A5.	Plant associations mixed with Hyphaene compressa (H.multiformis, H. thebaica) or Doum palm and/or new plantations related to urban development.	208,297	5%
A6.	Plant associations of dwarf bushes and sparsely scattered non-uniform grassland, with the presence of erosion of the herbaceous layer	446,834	11%
A7.	Plant associations of bushes and dwarf bushes with annual herbaceous species, with a scarce presence of Acacia ssp. and Commiphora ssp.	132,815	3%
A8.	Areas with decaying vegetation or without vegetation	2,646,094	69%
	TOTAL SURFACE 390,84 ha.	**3,908,403**	**100%**

The vegetation of the area is thus subjected to a very heavy pressure, due to the increase of the resident population over the past decade[5], both for its use as fuel and as timber for building new dwellings, in addition to the increase in cattle heads which graze on anything they find and to the felling of trees for 'export' purposes.
This increase in the use of plant resources has reduced its pres-

Fig. 16 Vegetation Map, abt 1/3.500, by the Turkana Scientific Research Group, 2010-15.

TOTAL SURFACE: 3.908,403 m2, 390,84 HA (100%)

- **A1 (171.370 m2; 4%)**: Palm grove plant associations with the prevalence of *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm and with some intrusions of *Prosopis juliflora*
- **A2 (145.463 m2; 4%)**: Palm grove plant associations characterised by the scarce presence of *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm, *Acacia tortilis or* Umbrella or White thorn and other bush species introduced by man, with an increasing presence of *Prosopis juliflora*
- **A3 (27.201 m2; 1%)**: Plant associations with a prevalence of *Acacia tortilis or* Umbrella or White thorn and Acacia ssp. with an increasing presence of *Prosopis juliflora*
- **A4 (130.329 m2; 3%)**: Plant associations with the presence of scattered groups of *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm, dwarf bushes and annual and evergreen herbaceous species.
- **A5 (208.297 m2; 5%)**: Plant associations mixed with *Hyphaene compressa (H.multiformis, H. thebaica)* or doum palm and/or new plantations related to the urban development and expansion.
- **A6 (446.834 m2;11%)**: Plant associations of dwarf bushes and scattered, non-uniform grassland with the presence of erosion of the herbaceous layer.
- **A7 (132.815 m2; 3%)**: Plant associations of bushes and dwarf bushes with annual herbaceous species, and the scarce presence of Acacia ssp. and Commiphora ssp.
- **A8 (2.646,094 m2; 69%)**: Areas with decaying vegetation or without vegetation altogether.

DETECTION ZONES

B1 Nursery Nanyori Group
B2 Turkana Village
B3 Rendile Village
B4 El Molo Camp-Lodge
B5 Samburu Village

DETECTED POINTS WITH INSTRUMENTATIONS (for date)

C1 28/08/2008 (4 aree)
C2 28/08/2008 (2 aree)
C3 29/08/2008 (2 aree)
C4 01/09/2008 (1 aree)

Water elements

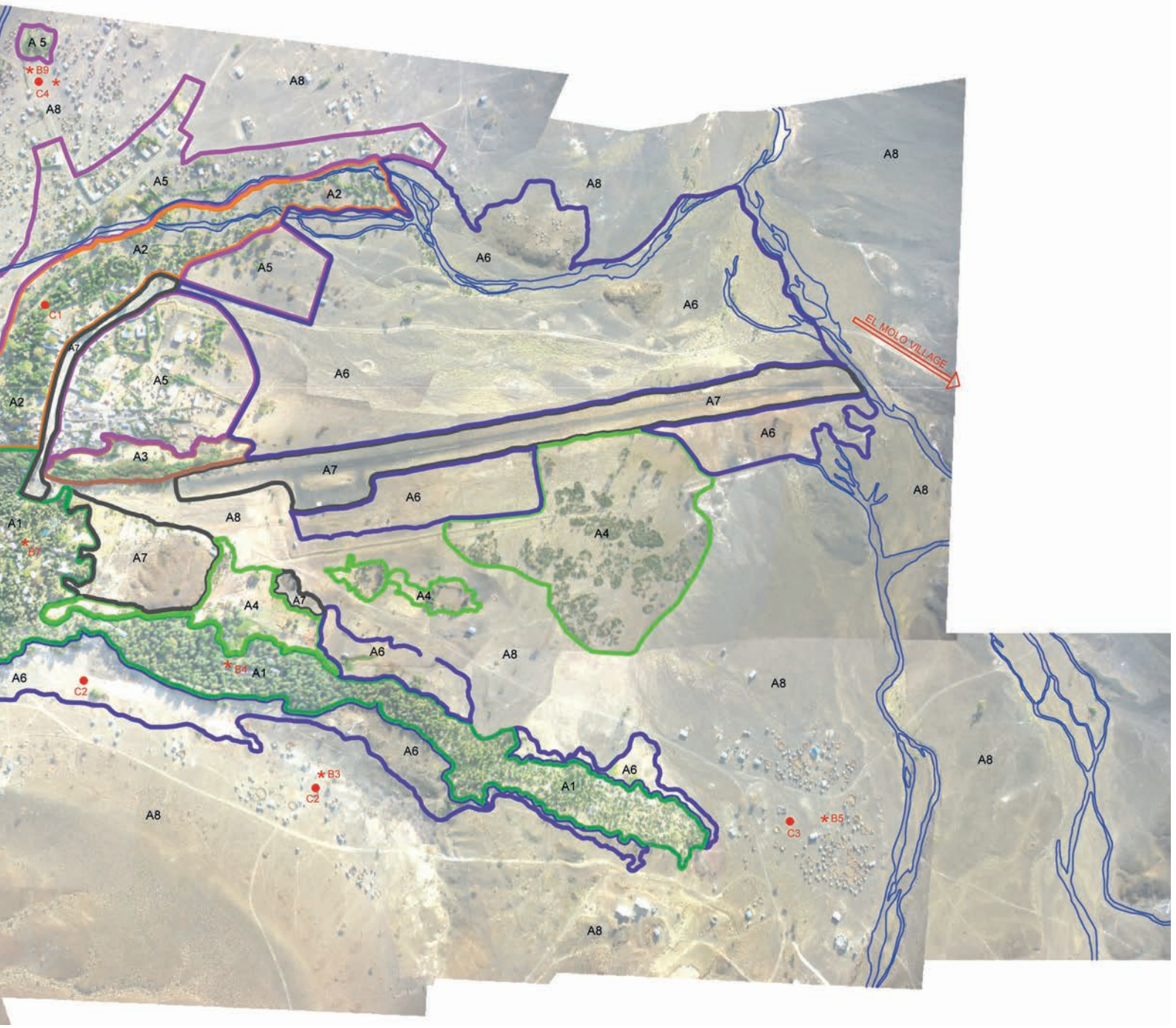

A 5
B9
C4
A8
A5
A2
A6
C1
A7
A3
A1
B7
A4
B4
C2
B3
B5
C3
EL MOLO VILLAGE

Fig. 17 Date palm grove and protection from the desert with natural enclosure. (Photo: L. Vallerini).

ence in wide areas, with the consequent increase of desertification. The urban development envisaged for the area as a consequence of the building, already in progress, of the new wind-power plant to the south near Sarima, as well as of the migration from the north due to war and drought (South Sudan, Ethiopia, Somalia), will increase even more the density of the inhabited center in the oasis and its surrounding areas, with an additional loss of vegetation, a reduction of available resources and an increase in the process of desertification.
In the absence of compensating interventions (increase of newly planted vegetation and control of superficial erosion), the phenomenon of desertification, which is augmented by the reduction of rainfall due to climate change or to the construction of great dams and hydroelectric plants envisaged in Ethiopia along the river Omo, with a consequent reduction in the level of lake Turkana, will tend to increase, with the risk of a loss of the oasis system (soil-vegetation-water) and a consequent socio-environmental crisis whose dimensions are not yet foreseeable.

Endnotes

[1] The main source of information on plant associations and the species mentioned is: Various Authors, 1991, *Range management handbook of Kenya – Marsabit District*, vol. 2, Published by Department of Kenya, Ministry of Livestock Development (MOLD), Range Management Division, Nairobi, Kenya.

[2] CBO or Community Based Organization.

[3] Founded in 2004, this NGO merged in 2010 with a new NGO, InterActions & Solidarity Monaco, with headquarters in France, Monaco-Montecarlo and Kenya, headed by Anne Wattebled (www.interactions-solidarity.org).

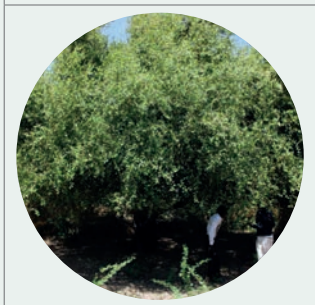
[4] Makishima H., 2005, *Flora and vegetation of Nachola, Samburu District, Northern Kenya: a study of vegetation in an arid land*, «African Study Monographs», no.32, pp. 63-78.

[5] The total population of Loiyangalani increased from 1,000 inhabitants in 2006-2008 to 5,000 inhabitants in 2016.

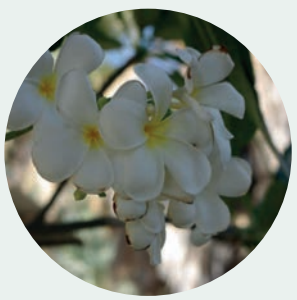
MAIN PLANTS EXAMINED

Lorenzo Vallerini

TREES AND SHRUBS	FAMILY GENUS – SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	MIMOSOIDEAE ***Acacia brevispica*** Wait-a-bit-thorn Turkana language *Ekurau* Samburu language *Girigiri* Native plant from East Africa it is a handsome tree that grows to a height of 1-5 m or an ugly shrub that grows up to 12 m in the bushland in arid zones in valleys along streams, but also in forests at altitudes up to 1800 m.	Medium-large shrub or small tree, very thorny 1-5 m The bark is gray, with dense, thin branches and very thorny (curved thorns up to 6 mm long), pinnated leaves, white flowers and fruits in the shape of long pods.	Bushland Dryland Very common in the area-good degree of rooting in Loiyangalani Pods and leaves are used as fodder, branches for making fences and as fuel. In traditional medicine an infusion of the roots is used as a remedy for stomach ailments, whereas a boiled extract of the roots is used as an afrodisiac and fertility enhancer and also for treating rashes and snake bites
	MIMOSOIDEAE ***Acacia senegal (l.) willd.*** Gum arabic acacia Turkana language *Ekonoit* Samburu language *Lolerikesi* Native plant of Africa, it is very widespread throughout Senegal and Mauritania, as well as in Eastern Africa from Erithrea to Ethiopia. It is also present in South Africa, the Middle East (Yemen, Oman) and in Asia (Pakistan, India). It was introduced in Egypt, Australia, Puerto Rico and the Virgin Islands. Its sap is the main source of gum arabic	Shrub or small tree deciduous, thorny 12-15 m Its size varies from small to medium and it can reach a height of 15 m. The colour of the bark varies from yellow-brown to black in old trees. Leaves are bipinnate. The small leaflets are oraganised into 7–25 pairs, linear, elliptical and oblong	Black-cotton soils or Vertisoils and stony soils semi-arid zones Good degree of rooting in Loiyangalani Acacia Senegal is used for recovering greenery in arid zones, the rehabilitation of the land and as windbreak. The resin of the tree is sold for making gum arabic, which is widely used in pharmaceutical products, tints, pigments, ceramics, watercolours, waxes, and the liquid gum is used for making fabric shinier, for thickening colours and for fixing colours in sweets and candies. In pharmaceutical products it is used mainly in the production of emulsions for throat inflammation, as an emollient in products for treating diarrhea, dyssentery, cough, throat irritation, fever, inflammation of the intestinal mucus, and for external use on inflammed surfaces such as burns, on nipples or in cases of nodular leprosy. It can be used as antitussive, for colds, inflammation of throat and nose, cough, as expectorant, and for gonorrhea, hemorrhages, tifoid fever, and infections of the urinary tract. Its main use is in food, for example as suspension or emulsion, stabiliser, flavour fixer and for avoiding the crystalisation of sugars, etc. It is used in practically all categories of transformed foods (candies, snacks, alcoholic and non-alcoholic drinks, bakery, frozen milk products, gelatines and puddings, cheese, breakfast cereals, fats and oils). Young leaves provide good fodder
	MIMOSOIDEAE ***Acacia tortilis*** Umbrella or White thorn Turkana language Ii *Etir* Samburu language *Ltepes* Tree which grows in the savannas of Africa and in the arid zones of the Middle East	Medium-sized 'umbrella-shaped' tree, thorny and with very deep roots (up to 35 m. deep) and which reaches heights of 18 m. It has long and straight (3-8 cm) as well as short and curved (7 mm) thorns. Fruits in pods, pink flowers with composite inflorescence and pinnated leaves. It is very important for the ecological equilibrium of savannas and arid zones	Shallow soils Semi-arid and arid zones Very common in the area-Good degree of rooting in Loiyangalani Very useful as timber and for feeding livestock; however in moments of hydric crisis and in the absence of herbaceous species it is felled for feeding livestock.

TREES AND SHRUBS	FAMILY GENUS – SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	APOCYNACEAE ***Adenium obesum*** Desert Rose – Elephant's foot or bottle tree Turkana language *Egales* Native plant of the regions of the Sahel to the south of the Sahara (from Mauritania and Senegal to the Sudan), tropical and sub-tropical Africa, Eastern and Arab Africa	Shrub or small tree, succulent 6 m Also known as Rose of the Desert or Oleander of Madagascar, it has a fleshy base which holds water and a ramified trunks at the end of which grow shiny oval leaves up to 10 cm long. Splendid tubular flowers up to 13 cm in diameter with colours that vary from pink to purple red or even white which blossom for a long time in small inflorescences at the extremity of the branches	Bushland. Stony soils Dryland Very common in the area The sap of this plant contains a toxin that is used by some ethnic groups for poisoning arrows for hunting
	MIMOSOIDEAE ***Albizia schimperiana*** Log-podded albizia	Medium-large tree 24 m	It is found in lowland forests, as well as in drier forests. It prefers wet soils. In Loiyangalani it is only present inside the oasis
	MELIACEAE ***Azadirachta indica*** Neem Tree Native of India; it is a robust, fast-growing tree which reaches heights of approximately 15 m, with a dense leafy foliage, generally evergreen, but not in prevailingly arid zones. It resists well to drought.	Medium-sized tree with a fast growth rate. Evergreen-deciduous in arid zones 15-20 m Gray-brown bark with composite leaves, cream-coloured flowers and many yellow-green oval fruits (they look like olives) that grow to 2mm long.	It resists well to aridity Medium-good degree of rooting in Loiyangalani It is a plant with many different uses: its wood is used for making tools, furniture, bowls, etc., and as fuel. The oil from its pods is used as a substitute of parafin for making soap and the remains of the pressing are used for livestock and as fertilizer. The leaves contain azadirachtin, a powerful insecticide; the dry leaves when burned keep mosquitos away, the extract of the leaves is used as insecticide against locusts, etc. The neem oil is used also for cosmetics or toot-paste. In traditional medicine the oil is used for treating skin ailments. The branches contain antisceptic ingredients useful for keeping teeth and gums healthy. Leaves are used for treating malaria. Many of these trees, precisely because they are so useful, green and shady, were planted in the village with medium-good results, in other words they have taken root but have not grown particularly well, considering its usual fast growth-rate, perhaps to to the high concentration of salts in the soil.
	BALANITACEAE ***Balanites aegyptiaca*** Desert Date Its natural distribution extends throughout all the arid areas to the south of the Sahara (Sahel), Malawi the Rift Valley and the Arab Peninsula	Small tree, evergreen, slow-growing very ramified and thorny 10 m	Black-cotton soils or vertisols and sandy soils Bushland Good degree of rooting in Loiyangalani The fleshy pulp of the fruit, both green and ripe, is edible and is eaten either dry or fresh. The fresh or dry leaves, fruit and sprouts are eaten by livestock. An experiment in Burkina Faso showed how this plant provides up to 38% of the dry matter grazed by goats in the dry season. The wood is hard, long-lasting yet easy to work, yet its small dimensions and its tendency to split makes its use at the sawmill difficult
	BURSERACEAE ***Commiphora africana or ssp.*** Commiphora It includes more than 200 species of trees and shrubs, native of Africa, Arabia and the Indian subcontinent	Shrub or small deciduous tree, very thorny 5-10 m	Stony and arid soils. Very common in the area Fragrant resins are extracted from many of these species, used for the production of incenses, perfumes and balms, among which mirrh (from Commiphora myrrha Arn.) and the Balm of Mecca (from C. gileadensis)

TREES AND SHRUBS	FAMILY GENUS – SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	CAESALPINIOIDEAE ***Delonix regia*** Flamboyant Fire Tree Plant of the family of the Fabaceae (Legumes) originary of Madagascar, known in many parts of the world, especially in the tropics, as 'Flamboyant' and in Italy also as Fire Tree ('Albero di fuoco')	Medium-sized umbrella-shaped tree with large red-orange blossoms. Fast-growing, deciduous 10-15 m	Prefers sandy soils, but grows throughout the tropics Good degree of rooting in Loiyangalani The fruit is a long (40-60 cm) pod which contains a few dozen dark oblong seeds, streaked on the edges, which recall sunflower seeds, with a medium-low germinability
	MORACEAE ***Ficus sycomorus*** Sycamore fig Turkana language *Echoke* It is a large deciduous tree which grows up to 21 m high near rivers or in areas with the presence of water, but also in the bushland or woods in more arid lands	Large deciduous tree with large edible fig-like fruit 21 m It is characterized by oval leaves with slightly dented edges approximately 8-12 cm long	It prefers rich and well-drained soils. It grows near rivers or in areas with the presence of water, but also in the bushland or woods in more arid lands. In Loiyangalani it is only found inside the oasis. The fruits are round and fig-like, of yellow-red colour and edible. The wood is used for building and from the inside of the roots a fibre is obtained for weaving. A decoction is made from the bark as a remedy for stomach ailments
	PALMAE ***Hyphaene compressa*** (H.multiformis, H. thebaica) Doum Palm Turkana language *Eengol* Palm native of the valley of the Nile in northeast Africa	Palm native of the valley of the Nile in northeast Africa with round edible, yet hard dates 18-20 m It is one of the few palms that branches out from a single trunk. It is a handsome plant and well-adapted to shallow soils, prefering however areas with the presence of water	Water abundant soils. In Loiyangalani it is found only inside the oasis or in areas where water surfaces. Oblong or ovoid edible fruits the size of a small tangerine, which come in bunches with a typical scent and taste and brown in colour. Leaves are often used for weaving the roofs of the local huts
	MIMOSACEAE ***Leucaena leucocephala*** (L.glauca) Very widespread in America, Africa and the South Pacific, it grows well in tropical and sub-tropical environments, as well as in the Mediterranean basin	Shrub or small tree, semi-deciduous 5 -20 m With leaves, pods and seeds it produces abundant fodder when frequently pruned	Calcaric or neutral, well-drained soils. Does not tollerate acid soils. It needs water. In Loiyangalani it is found only inside the oasis. It has positive effects on the preservation of the environment. It produces large quantities of biomass. Its production of fodder (50/t/ha/year) is very large as well, especially when it is cultivated properly (including pruning, etc.). The leaves and legumes can be used for grazing or as fodder to be distributed at the trough. The leaves remain green for a long time, thus making good fodder available even during the dry season, when grazing lands and other forage areas have become arid and less nutritious. Due to its tastiness, digestibility and good nutrition value, fodder from the Leucaena can be considered as a good alternative of food for livestock
	MORINGACEAE ***Moringa stenopetala*** Moringa Samburu language *Lorsanjo* Native plant of northern Kenya and southern Ethiopia	Medium-sized tree characterized by pods as long as 45 cm 10-12 m height Soft, shiny green leaves. It often grows along the shores of lakes and rivers, but also in arid areas (often with rocky soils) at an altitude that can vary between 450 and 1200 m above sea-level. The trunk and bark are white, the leaves are composite and pinnate, flowers are white or yellowish, scented and numerous, the fruits are long and encapsulated in a whitish pod	It needs well-drained soils but rich in water. It resists well to aridity. Good degree of rooting in Loiyangalani While the ground seeds are used for purifying water, roots are used as medicine for the stomach, whereas an infusion of the leaves is used traditionally for fighting fever and even leprosy. It has an important role in Africa as food; its leaves are sold in the local markets as a vegetable which is used in a local dish that is consumed daily called dama; it is a cereal dumpling, generally sorghum, wrapped in boiled Moringa leaves

TREES AND SHRUBS	FAMILY GENUS – SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	CAESALPINIOIDEAE ***Parkinsonia aculeata*** Jerusalem thorn	Small, fast-growing tree, thorny 5-10 m Small tree with a thorny trunk, many branches, and light foliage with long stems that support many long and thin leaves	It tollerates saline or alcaline soils, poor, sandy and eroded soils. It does not tollerate the constant presence of water. It grows well in arid and semi-arid regions. Medium rooting in Loiyangalani Well-known tree widely used as ornamental plant and for hedges in hot regions. Leaves and pods are used for fodder for livestock in times of emergency, as well as by wild fauna. Bees make honey from its scented flowers
	PALMAE ***Phoenix reclinata*** African Wild Date Palm Turkana language *Euogomamur* Plant of the family of the Arecaceae, endemic of tropical Africa, from Madagascar to the Comoro Islands	Palm with edible dates 10 m This plant can be found at sea-level and up to an altitude of 3000 metres in rainforests and in monsoon forests	Soils rich in water In Loiyangalani it is found only inside the oasis or in areas where water surfaces In addition to the fruits-dates, the heart of the palm can also be eaten, The sap is used before flowering for making palm wine. The fibre from young leaves that have not opened yet can be used for making mats, kilts and brooms. The roots, rich in tannins, can be used for producing a brown pigment. The also produce an edible gum. The wood is light and not much used
	MIMOSOIDEAE ***Prosopis juliflora*** Algarroba Turkana language *Eterai* Thorny shrub native of Central America-Mexico	Fast-growing thorny shrub native of Central America-Mexico, it can become a 15 m high tree	Tolerates sandy, rocky or poor and saline soils. Grows well in arid zones and becomes invasive in the presence of water. It was imported to Loiyangalani becoming widespread at a fast rate This very fast-growing plant is cultivated in tropical lands and grows well in arid zones in poor and saline soils up to an altitude of 1,500 m: in the presence of water it becomes invasive. The fruit, long sweet pods, and the leaves are eaten by livestock, yet produce negative effects on the animals, sometimes causing their death, often because of the thorns which are difficult / impossible to digest. The plant, a sort of vegetable 'alien', is spreading in an alarming way in many sections of Loiyangalani and may become a serious environmental problem with risks for the health of both animals and humans. In other areas of the region, such as the district of Baringo, along the shores of lake Turkana (from the airplane long green strips can be seen along the shore and shallow waters) and in the district of Tana River, this plant has colonized vast areas supplanting the local vegetation, with serious risks for wild fauna as well. If solutions are not found for eliminating it (it is difficult to uproot and if felled grows back faster and stronger) it may contribute to the disappearance of the oasis
	APOCYNACEAE ***Pulmeria alba*** Frangipani	Small succulent evergreen tree-shrub with white blossoms (or red, var. rubra) 5 m	Grows well everywhere. Imported for ornamental purposes to Loiyangalani (Oasis Lodge)
	EURPHORBIACEAE ***Ricinus communis*** Castor-oil plant Native of tropical Africa, it is widespread throughout the world in places where the climate is appropriate. It is found in sub-tropical and areas with temperate climates	Ligenous herb 1-5 m The castor-oil plant is an annual or perennial shrub depending on climate conditions. It has an average height of 2-3 metres and a maximum height of 10 metres in its area of origin (tropical Africa)	Grows well in various types of habitat, from the bushland to humid forests. Medium-low level of rooting in Loiyangalani Castor oil is produced from the plant, which possesses virtues other than those related to intestinal remedies: it is useful for restructuring damaged hair and for a series of ailments such as chronic constipation, gall-bladder ailments, arthritis and other abdominal ailments

TREES AND SHRUBS	FAMILY GENUS – SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	RUTACEAE ***Salvadora persica*** Toothbrush tree Turkana language *Esekon* Endemic plant in many areas of Africa	Greatly ramified evergreen shrub or small tree. Typical of the entire area 3-7 m Its bark is rough and peeling, white and with bending extremities. The skin of the root is similar to sand and the internal surface is light brown. It has a pleasant smell and a warm and pungent taste. It loses its leaves from the end of December to January	It grows in arid areas and soils rich in salts, but can also grow in clayey-sandy soils along watercourses. Very resistent to drought Good degree of rooting in Loiyangalani It adapts very well to alcaline and very saline soils, usually clayey, but also to non-saline soils. It prefers clay, but can also be found on clayey-sandy soils (FAO 1988). Very well adapted to arid conditions and very resistant to drought. If cultivated must be protected from grazing by animals (FAO 1988). The roots of the plant are used by locals for cleaning their teeth; in some internet sites the odontoiatric qualities of this plant are highlighted, as is its use in the production and sale of odontoiatric products with Salvadora persica as the main ingredient. Used over the centuries as a natural toothbrush, its fibres have been promoted by the World Health Organization for their use in oral hygiene. Research shows that the plant has a vairety of beneficial medical properties. It is antiseptic, detergent and astringent
	CAESALPINIOIDEAE ***Senna obtusifolia*** Turkana language *Emany* Native of several parts of the world. Invasive	Ligneous herb or small shrub, invasive in cultivated areas 0,5-2 m With flowers and pods from 10 to 25 cm long	It grows along the shores of lakes and rivers Medium-low level of rooting in Loiyangalani The green leaves of the plant are fermented to produce a high-protein food product called 'kawal' which is eaten by many people in Sudan as a meat substitute. Its leaves, seeds, and root are also used in folk medicine, primarily in Asia. It is believed to possess a laxative effect, as well as to be beneficial for the eyes. As a folk remedy, the seeds are often roasted, then boiled in water to produce a tea. The plant's seeds are a commercial source of cassia gum, a food additive usually used as a thickener and named for the Chinese Senna's former placement in the genus Cassia. Roasted and ground, the seeds have also been used as a substitute for coffee
	PAPILIONOIDACEAE ***Sesbania sesban*** (S. aegyptica) River bean or 'Loiyangalani Tree'	Fast growing shrub or small deciduous tree that has the capacity of fixing nitrogen in the soil 6 m	It is found near areas where water is abundant and especially along the shores of lakes or even inside the water, but it also adapts well to acid or saline soils. Good rooting inside the oasis of Loiyangalani With composed leaves, yellow flowers and long seeds that resemble a legume, it is characterised by a light maleable wood which is good for light constructions. A poultice made with the roots is excellent as a remedy for scorpion bites
	CAESALPINIOIDEAE ***Tamarindus indica l.*** Tamarindo Turkana language *Epeduru* Samburu language *Roka* Native plant from Madagascar and Eastern Africa, very widespread throughout semi-arid Africa, in India and many tropical countries. In Senegal it is present mostly in the sudano-sahelian and sudanian zones	Large tree with wide and dense foliage, evergreen and deciduous in arid areas 30 m Tamarind is an evergreen tree with a characteristic trunk that ramifies from its base, with a height usually between 12 to 25 m, with dense foliage that prevents the passage of sunlight, to such an extent that other plants do not grow below it. It is a long-living plant	Very adaptable to arid and semi-arid soils, tollerates saline soils but prefers deep alluvial and well drained soils. Medium rooting in Loiyangalani The fruit of the tamarind is rich in sugars, proteins, pectin and organic acids (citric, tartaric and malic). It is used as an acidifier in many dishes, drinks and marmellades. The integument of the grains is used in the textile industry, for dyeing or tanning. It is also known as a laxative by modern medicine, and according to the popular tradition has laxative, purging, diuretic, healing, antipyretic, and antiparasitic properties
	RHAMNACEAE ***Ziziphus mucronata*** Buffalo-thorn Turkana language *Ekalale* Samburu language *Ilerendei*	Shrub or small tree present in these regions, very thorny with a round crown and sour edible fruit 7 m	Has a highly developed root system, but prefers soil with the presence of water. Grows also in the Bushland Excellent rooting results in Loiyangalani Its wood, robust and elastic, is used as building material (stakes), as fuel and for producing charcoal, leaves and fruits are used as fodder; many uses also in traditional medicine with poultices made from the roots and leaves for skin infections and pustules, decoctions from the bark for rheumatism and stomach ailments, decoctions of the bark for snake bites

PROJECTS AND WORKS

A palm grove in an Oasis in Tunisia. (Photo: L. Vallerini).

The reconstruction of the Oasis

A meeting with local authorities and the Nanyori Group to plan the future works and interventions, 2011. (Photo: M. Cassitelli).

Yemen, terracing system for the protection and cultivation of the slope. The water intakes deviate the flows from their natural course and direct them along the walls on the terraces. Towers and stone buildings are placed to defend the cultivations. **Photo: P. Laureano.**

UNCCD – The United Nations Convention to Combat Desertification

The international community has long recognized that desertification is a major economic, social and environmental problem of concern to many countries in all regions of the world. The question of how to tackle desertification was a major concern for the United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in 1992. The Conference supported a new, integrated approach to the problem, emphasizing action to promote sustainable development at the community level.
It also called on the United Nations General Assembly to establish an Intergovernmental Negotiating Committee (INCD) to prepare, by June 1994, a Convention to Combat Desertification, particularly in Africa. The Convention was adopted in Paris on 17 June 1994.

Committee on Science and Technology

The UN Convention to Combat Desertification has established a Committee on Science and Technology (CST). The CST was established under Article 24 of the Convention as a subsidiary body of the COP, and its mandate and terms of reference were defined and adopted during the first session of the Conference of the Parties (COP) in 1997. It is composed of government representatives competent in the fields of expertise relevant to combating desertification and mitigating the effects of drought. The committee identifies priorities for research, and recommends ways of strengthening cooperation among researchers. It is multi-disciplinary and open to the participation of all Parties. It meets in conjunction with the ordinary sessions of the COP. The CST collects, analyses and reviews relevant data. It also promotes cooperation in the field of combating desertification and mitigating the effects of drought through appropriate sub-regional, regional and national institutions, and in particular by its activities in research and development, which contribute to increased knowledge of the processes leading to desertification and drought as well as their impact.

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UNCCD

Promotion of Traditional Knowledge: A Compilation of UNCCD Documents and Reports from 1997 - 2003

UNCCD

Oasis of Timimoun (Algerian Sahara), kesria, a water quota sharing system. **Photo: P. Laureano.**

Promotion of Traditional Knowledge

A Compilation of UNCCD Documents and Reports from 1997 - 2003

UNCCD

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Projects and interventions

The UNCCD document on the promotion of 'traditional knowledge' (Source: UNCCD 2005, *Promotion of Traditional Knowledge. A compilation of Documents and Reports from 1997-2003 UNCCD*, Bonn, Germany).

Lorenzo Vallerini

The project intervention strategies

In 1992, the *United Nations Conference on Environment and Development* (UNCED), also known as the Rio de Janeiro Earth Summit, initiated a mobilisation of the international community in favour of a treaty that would help combat desertification.

With the *United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa* (UNCCD)[1], adopted in Paris in June of 1994, the executive phase was initiated and the first worldwide conference took place in Rome at the headquarters of FAO during the months of September and October, 1997.

On that occasion, Kenya ratified the Convention for a more incisive commitment in its territory and in other areas of East Africa. Today in Kenya the NDMA-National Drought Management Agency[2], together with the Counties involved, carries out a constant activity in the regions of North Kenya.

The Convention is greatly innovative in terms of international policy since it privileges the interests of the communities directly affected by the phenomenon and substitutes the traditional concept of 'assistance' with that of cooperation and participation with the local populations.

The Convention, in a holistic approach to the fight against desertification, addresses all the issues regarding the degradation of the soil and the destruction of the natural resources.

Article 1, 'Definitions' of the Convention establishes that:

> 'desertification' means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities;
>
> [...] 'combating desertification' includes activities which are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development which are aimed at:
>
> 1. prevention and/or reduction of land degradation;
> 2. rehabilitation of partly degraded land;
> 3. reclamation of desertified land;
>
> [...] 'land degradation' means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:
>
> 1. soil erosion caused by wind and/or water;
> 2. deterioration of the physical, chemical and biological or economic properties of soil;
> 3. long-term loss of natural vegetation.

The large-scale themes of the Convention, in an extremely summarised form, regard five categories:

1. water;
2. soil;
3. vegetation;
4. the use of appropriate (or traditional) technologies;
5. the involvement of local populations, the reinforcement of their capacities through education and awareness of the problems derived from desertification.

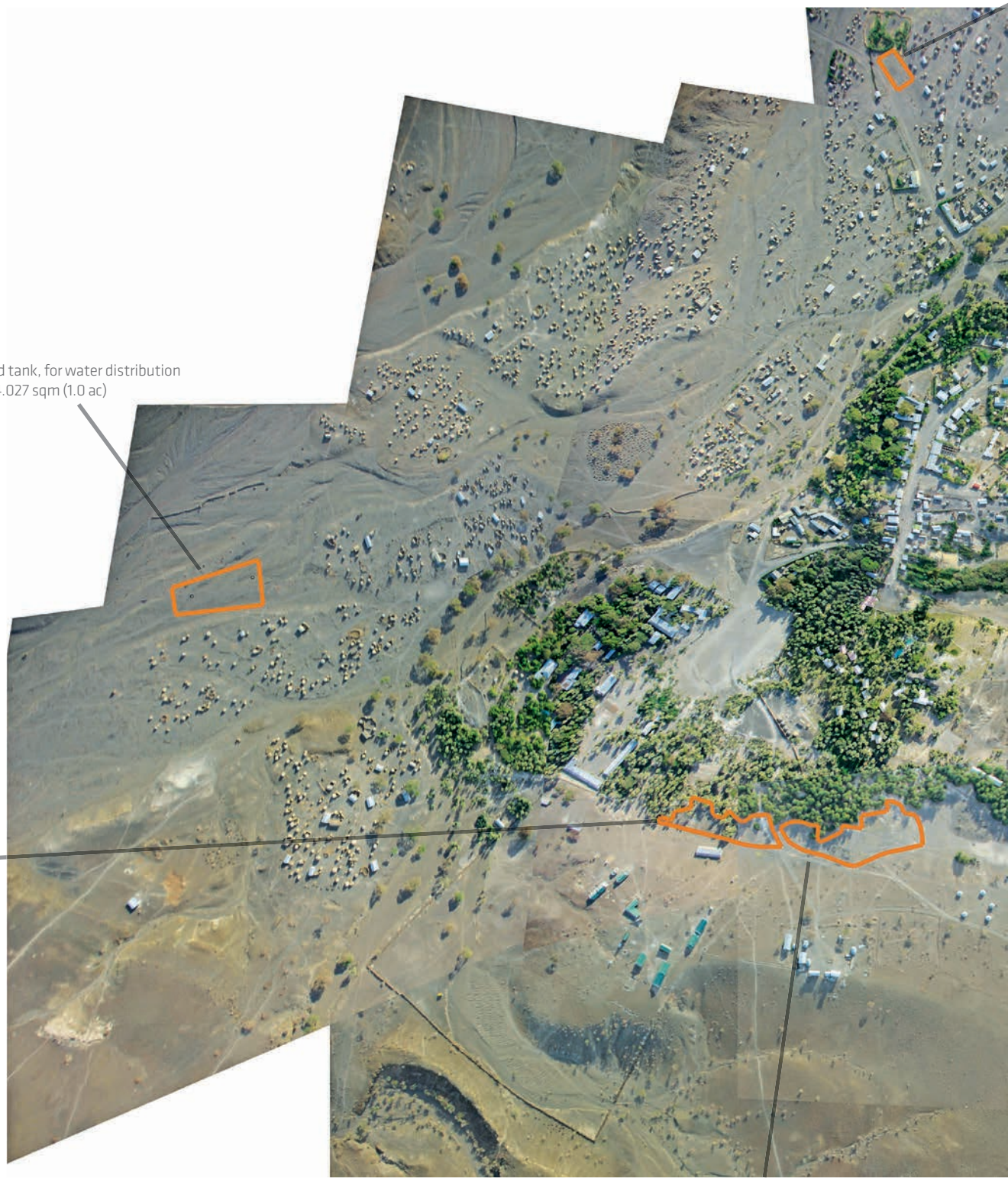
The actions and works of this project operate within this general framework, aiming the various interventions in accordance to the specific local situations determined by the analyses and surveys carried out.

First of all it is necessary to identify efficient and affordable measures for the regeneration of the soil, based upon the participation of the local communities, with the immediate purpose of stopping the process of desertification and subsequently of valorising the land and establishing plant associations capable of regenerating themselves.

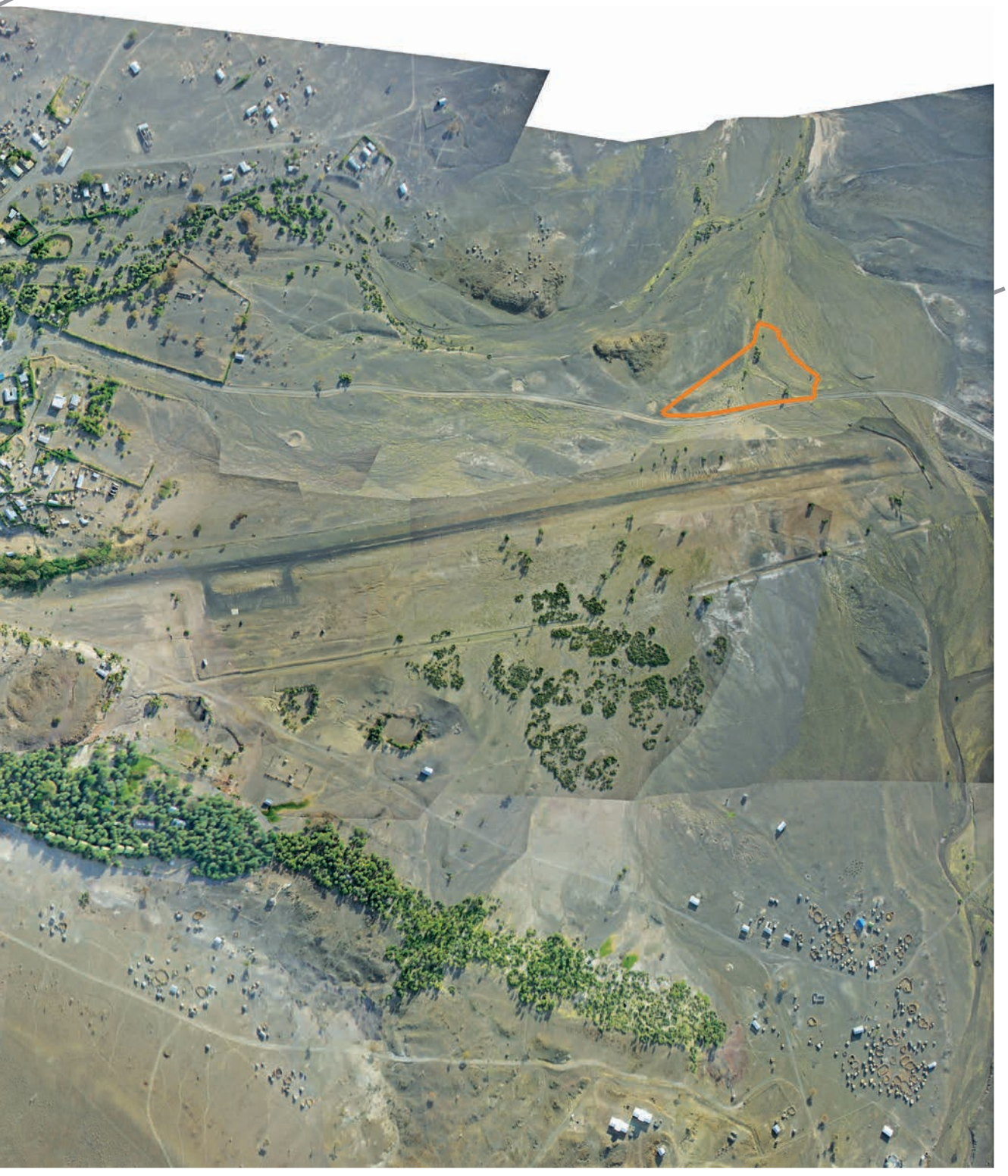
The presence of the oasis and of fresh water, including from thermal sources, intensively used and with some signs of degradation, is however a good basis on which to support the envisaged interventions.

Another fundamental element was the identification of new water collection points. For this purpose a series of hydrogeological and geoelectric studies were undertaken which beginning with the iden-

Fig. 1 The five areas of intervention in an aerial photograph of 2008 (TSRG). (By L. Nofroni).



PROJECT 4
Monitoring and comunication centre, small nursery, compost plant: 854 sqm (0.21 ac)



PROJECT 3
Grass of Vectiveria zizanoides linn. for pasture: 8.395 sqm (2.01 ac)

Fig. 2 Desertification is "the process that brings to a progressive and not reversible reduction of the soil capacity to produce resources and services" FAO-UNEP-UNESCO, 1979. (Photo: G. Ceccanti, 2011).

Fig. 3 Palm groves at Chebika in Tunisia. (Photo: L. Vallerini, 2016).

tification of specific areas of interest, determined with precision the places where to drill, focusing the attention on the qualitative and quantitative safeguarding of the existing resources. This was possible by applying consolidated research techniques that range from remote sensing from aerial photographs and satellite images, to indirect studies of a geophysical nature, all of which aimed to the reconstruction of the underground structures in order to define the local hydrogeological characteristics and to determine the exact spots for the perforation of the new wells.

Finally, the techniques adopted for the carrying out of the proposed projects were based as much as possible on the local 'traditional knowledge', that is using traditional technologies as well which are usually used in other contexts, yet appropriate to the technical capacities of the local population and the materials available in the area of intervention.

The reference, however, is the UNCCD document on the *Promotion of Traditional Knowledge,* which gathers all scientific documents and reports on the subject for the period between 1997 and 2003[3].

Other studies carried out in Kenya on Traditional Knowledge for the combat against desertification are also available, which focus on the region of the Kaisut Desert and Hedad to the north and east of the city of Marsabit and on the Rendille and Ariaal ethnic groups[4]

The project as a whole aims at becoming a 'demonstrative project'concerning the fight against desertification in the wide basin of Lake Turkana and other geographic areas with similar characteristics, using precisely traditional knowledge and its innovation-evolution, together with other appropriate or 'soft' technologies to be shared with the local populations.

In fact, in line with UNCCD provisions, the process of empowerment of local populations plays a fundamental role in the success of the project. To this purpose *Information and Awareness* activities regarding the various topics of the project were carried out, with the purpose of involving the locals, who are the end users of the entire intervention, in the construction and later in the management of the various projects and their subsequent expansion, as well as *Tutoring and Training* activities carried out by experts from the *Baraka Agricultural College* (Nakuru) together with a group of people from the CBO Nanyori Group (see the chapter on Information and Awareness).

The five projects presented below are the starting point and a practical demonstration of feasability for the local authorities and population who, once the techniques and capacities have been acquired, may and must apply them at a larger scale, bettering the soil, expanding the areas of consolidation of vegetation and managing the water resources as a whole in order to expand-enlarge the ecosystem of the oasis, which is currently in a process of thinning out, and for favouring a truly sustainable economic and social development.

Otherwise the alternative for these populations will be a forced migration toward other areas in the country or abroad, which will also entail the loss of their cultural identity.

The advanced state of the works both on the construction of an enormous aeolian power plant near Sarima (approximately 60km from Loiyangalani), as well as on the great dams on the river Omo to the north in Ethiopia (which entails a reduction of the water supply to the lake) seem to act against sustainability in a social and ecologically fragile environment. Certainly the local communities and environmental balances will need to find ways to adapt and coexist with

Fig. 4 The location for the new well in the wadi. (Photo: L. Vallerini, 2017).

these great infrastructure works decided from above, perhaps even trying to turn these transformations to their advantage.

It is due precisely to these important changes, combined to the more general climatic changes, that it is increasingly urgent to initiate strong processes of consolidation of the existing environmental-social system. Without them there appears to be no hope for survival in the near future.

Five projects for fighting desertification and enhancing the quality of life of the local populations

As previously mentioned, the study and research phase provided an overview of the state of health of the oasis of Loiyangalani and of its immediate surroundings, over a surface of approximately 390 hectares.

It is within this wider area that five intervention zones were identified with pilot projects that allowed experimentation with different forms of action based on a combined and interdisciplinary scientific approach regarding:

1. Access to water and the construction of new distribution points;
2. Reconstruction of the plant ecosystem of the oasis in two areas, both with productive date palm groves and the planting of trees and shrubs;
3. Reconstruction of the areas devoted to the production of fodder;
4. Construction of a new Nursery, a compost plant and a building for the Monitoring and Documentation Centre.

The criteria for choosing the location of these areas vary in relation to the environmental conditions observed (altitude, morphology, natural drainage system, soil, vegetation), the vicinity of existing water collection points, the needs of the residents of Loiyangalani and the properties of the soil.

Regarding the access to water and the construction of new distribution points, the choice fell on an area of 4.027m^2 (1.0 acres) situated to the south-west of the *'Wadi'* (or seasonal stream), locally known also as *'Laga'*, in a section of the village inhabited mostly by the Turkana ethnic group which has few points of water supply points; in this area geoelectric tests were carried out which confirmed the presence of water.

Regarding the reconstruction of the plant ecosystem of the oasis, above the oasis (to the east, toward the police station and secondary school), in close vicinity to the existing vegetation and next to the sources, the choice involved two adjacent areas characterised by very shallow and sandy-loamy soils, carbonate but not very saline, and by the loss of the herbaceous layer due both to erosion and to the thinning out of the tree and brush structure of the oasis.

In an area of approximately 5.635m^2 (1.40 acres) a Palmeraie was created, that is a grove of date palms and other fruit trees and vegetables, whereas in another area of 3.379m^2 (0.83 acres) a process of afforestation was initiated through the planting of local bushes and trees with the aim of enlarging the plant ecosystem of the oasis.

Regarding the reconstruction of the areas devoted to the production of fodder, an area was identified of approximately 8.395m^2 (2.01 acres) adjacent to the landing strip to the west, used today for wild grazing and characterised by a strong loss of the herbaceous layer due to excess grazing and erosion, with relatively deep soils, very alkaline on the surface, with a tendency to crusting and with problems regarding seasonal drainage; in this area the cultivation of *Vetiveria zizanoides* was initiated and developed, for the production of fodder for livestock to be used in times of crisis and drought.

Regarding the new Nursery and compost plant and Monitoring and

Fig. 6 Effects of erosion from excess grazing and foot traffic. (Photo: L. Vallerini, 2008).

Fig. 5 New plantation in a single patch. (Photo: L. Vallerini, 2008).

Fig. 7 The area for Vetiveria before interventions. (Photo: L. Vallerini, 2011).

Documentation Centre (M&C Centre), or *Nanyori Area*, the choice fell on an area of approximately 854m^2 (0,21 acres) to the west, in a section of the village inhabited mainly by the Turkana, and characterised by urban development, with soils that do not present symptoms of degradation (soils that are only slightly alkaline and saline), with scarce and often absent vegetation, yet in a process of expansion, especially in the proximity of the existing public fountain already in use by the local CBO, the Nanyori Group.

Four of the five areas of intervention are on 'common land', temporarily assigned to the recipients of funds from the European Union (VSF-Germany and WRF-Italy) by the County of Marsabit[5] in December 2015, whereas the fifth area, which was destined to the M&C Centre, is on private property, as was previously mentioned, and has been allotted for some time to the CBO Nanyori Group.

At the end of the project (February, 2018) all the areas in which interventions were carried out were given back to the communities in a *handover* ceremony.

Area Project 1. New Well and Water Distribution System to the Population

The oasis of Loiyangalani is located at the place where most of the drainage of the water from the western side of Mount Kulal, an imposing basaltic shield with an altitude of over 2.300 metres which represents the eastern boundary of the great tributary catch basin, is collected. The humid currents coming from the lake are discharged as rain on this massif and represent a continuous supply for the alluvial aquifers that are formed along the waterways.

The oasis of Loiyangalani developed around a series of thermal springs (the chemical analyses regarding the quality of these waters gave optimal results) which for a vast arid, almost desert region effectively represent the only source of drinking water and the only possibility for carrying out livestock farming and providing a minimum degree of sustenance. All of which takes place on the shores of a lake whose waters are not adequate for drinking or watering purposes. The long-standing experience of the El Molo demonstrates[6] that when used over long periods of time it is harmful for the health of both humans and animals.

But this large amount of water from the springs which has supported the palm grove and many plant associations in the oasis, has begun to be in short supply due to the reduction in the amount of water that arrives to the springs, and also to the fact that, forced by penury, a growing amount of people have settled in this area which is now too densely populated.

It was therefore considered important to increase access to drinking water, not only from the existing springs, but also from other collection points, taking advantage of the waters that flow underground below the great rivers *Wadi* to the north-east and south-west of the oasis and other areas of the villages.

The study carried out highlighted the possibility to locate good areas for drilling for water along the south-west of the oasis, along one

of the *Wadi* that passes by the Turkana village. It is outside the urban area, which permits avoiding the polluting infiltration from the cemetery and the sewage from the latrines (the are must henceforth be protected from any form of urban development).
Once the well was made, as we shall see in detail below, in accordance with the needs indicated by the local authorities, it was connected to a system of water distribution for the inhabitants of the village; the water is pumped from the well to two tanks placed at an elevation by a solar-powered pump, and from there it is delivered through pipes by gravity to the western section of Loiyagalani where it is distributed to the population at a public water fountain.

Area Project 2. Palmeraie and Area Project 5. Afforestation

How did the oasis of Loiyangalani develop? Is it the remainder of a larger ecosystem or the result of a series of natural actions (the underground waters descending from Mount Kulal)?
We cannot provide an answer to these questions, yet perhaps the entire area long ago was part of a large savanna with fertile soils and numerous species of animals. The high concentration of salts in the soil as a consequence of the progressive reduction over millennia of lake Turkana has surely always been an issue, yet in the past it was counteracted by a thin crust of fertile soil which supported the existence of an ecosystem far richer than the current one.
The presence of increasingly unfavourable climate conditions (increase of drought and strong winds) and excessive grazing (mostly goats today, but many still remember the presence of herds of cows grazing in the area until a few decades ago, when they migrated to the green slopes of Mount Kulal) have broken a very delicate balance, generating the desertification of large areas.
The oasis of Loiyangalani remains, however, a last outpost against desertification, although a very fragile one.

> The soil, the water and vegetation are linked in a process of interaction such that the absence of any of the factors causes the lack of the other, continuously amplifying the processes of biological degradation and impoverishment, in an increasing spiral of desertification[7].

Thus Pietro Laureano summarises the problem while also indicating the solution, in other words the reconstruction of what he defines as the *Oasis Effect*, that is the establishment of a virtuous circuit capable of self-propulsing and self-regenerating that can ultimately reverse the *Desert Effect* by creating niches and micro-environments in opposition to it.
This second project is aimed at reestablishing the proper conditions, in the areas surrounding the oasis, which can first of all limit the loss of the soil and then subsequently establish a progressive self-regenerating process of re-vegetation.
In 2008 new plantations were carried out by the Nanyori Group, as a part of the Wings for Earth-WFE programme, but isolated and unsatisfactory in terms of ecosystem reconstruction. It was therefore necessary to reconstruct, after the adequate interventions to enrich the soil, a sequence of plantations capable of self-reproduction with as little human intervention as possible.
Last but not least, this project aims as well at the insertion in the oasis of trees and bushes that can, on the one hand, help reestablish the typical varieties originally present in the oasis (today there is a mono-culture of *Doum Palm*) so as to enrich the ecosystem and make it more stable, and on the other, that can provide support for the local communities in terms both of foodstuff and commerce.
The two chosen areas for the Palmeraie and for *Afforestation* lie at an elevation bordering the oasis to the east and adjacent to the Police Station, and are characterised both by the loss of the herbaceous layer due to erosion and to the thinning of the tree and brush system within the oasis; this notwithstanding the vicinity to one of the most

important springs in the oasis. This is due mostly to strong anthropic and animal pressure in the area in question.

The area where the palm grove was established is the one closer to the natural springs of the oasis, which are already widely used by the locals. The palm grove, which requires large amounts of water in order to be cultivated and to become productive, needs to obtain the water from these same sources.

But why a palm grove of *Phoenix dactylifera* L. (and/or *Phoenix reclinata*) and not of *Doum Palm,* which already spontaneously grows in the oasis? Because the *Date Palm*, unlike the *Doum Palm*, produces edible dates with very high nutritious value which, if the production surpasses the local consumption needs, are also easily sold to other areas of the County and/or the country[8]. Additionally, the date palm also favours the reconstruction of the fertility of the soil and, therefore, the cultivation of other plants and trees.

The main objective, therefore, was not only to widen the surface with vegetation in the oasis and to stop the process of degradation of the soil, but also to create an area that provides food for the local population, not only of dates, but also other fruit trees and vegetables. This also permits involving the local community as much as possible in the management of the area and provides jobs.

The large square surfaces of 100x100 metres into which the area is divided, one for each palm with four fruit trees and vegetable gardens under it, are irrigated by a system of canals that allows the distribution and control of the water by gravity, adopting the traditional methods used in North Africa, where throughout the centuries the cultivation of palm groves has been used to colonise the desert.

The other Afforestation area was originally envisaged in the proximity of the area of the Nanyori Group as an *Open air nursery,* that is as a place where to cultivate forest plants to either transplant in that area or to sell; in fact this activity is already carried out at the premises of the Nanyori Group, with an efficient nursery cultivation, seedbeds, etc.

This area, which is adjacent to the Palmeraie and was originally devoid of vegetation, was chosen for experimenting with the planting and cultivation of tree and bush species that are suitable for the protection of the soil from the various forms of erosion (aeolian, hydric, anthropic, etc.) and from the beating sun that menace the existence of the oasis, as well as for expanding the area of the oasis that is covered in vegetation.

The various species chosen were selected among those originally existing in the ecosystem of the oasis (many of which are no longer present today in large sections of the oasis due to the degradation of the soil and the intensive usage of the oasis itself) as well as among other autochthonous species of the area. Plants which are both adaptable to the difficult environmental conditions and adequate for the reconstruction of the topsoil vegetation, but also a source of food (the diet of the local population today is limited to goat products, fish and very few vegetables and fruit), or which can be used for the production and trade of commercial products, including those for cosmetic-pharmaceutical usage.

Some examples are the dates of the *Balanites aegyptica,* which are rich in protein, or the gum Arabic obtained from the *Acacia Senegal,* which is commonly used in the production of soft drinks, or the oil of the *Neem Tree,* used in the production of soap, cosmetics and against insect bites, the roots of *Salvadora persica,* which are used

Fig. 8 Vetiveria zizanioiodes cultivation along motorway at Nairobi. (Photo: L. Vallerini, 2016).

Fig. 9 Vetiver plants before planting in Loiyangalani. (Photo: L. Vallerini, 2017).

as a dental whitener, the grains and fruit of the *Tamarindus indica* for both drinks and as food, the leaves and oil of the *Moringa oleifera* (known also as the 'miracle tree'), which is very rich in nutritious substances, etc. These products can be combined in the future with those of the *Palmerie* and constitute an additional source of nutrition, as well as an opportunity for economic development.

Last but not least, the two areas were fenced in and protected by a system known as *Marara*, which is already widely used in Loiyangalani, made with the dry palm leaves and other vegetation, weaved and tied to each other so as to form a protective barrier against the strong winds and invasive domestic animals (goats).

Once the system is consolidated in these first experimental areas, it may be reproduced in other adjacent areas so as to expand the oasis and offer additional job opportunities.

As mentioned above, the construction of the palm grove, as well as of the tree plantations and the other areas, was accompanied by information and tutoring-training activities aimed at convincing and teaching people culturally used to 'nomadism', yet today sedentary, to become vegetable growers. This process will take time and will certainly extend beyond the completion of this project.

Area Project 3. New Areas with Vetiveria zizanioides Linn.

An important cause for the increase in desertification is wild excess grazing, until a few years ago of cows, and today of thousands of goats; approximately 50% of the livestock grazes on arid and semi-arid land both in Kenya as a whole and in the region of Turkana, and represents the main resource for many of the local communities. The possession of a great number of head of cattle also represents a question of social status for these ethnic groups, which remain 'shepherds' although they have become sedentary, and the preservation and increase of this capital is for many members of these communities the main objective of everyday activities, even in detriment of other economic initiatives. In fact, even from the cultural point of view, the link that unites humans and goats is so strong that, in times of drought, the community prefers to fell trees (especially Acacias) for feeding the goats, with the consequence of a reduction in the plant mass in the area and in detriment of the human community.

The animals are taken to graze as well on the green meadows inside the oasis itself, which become smaller every year through superficial erosion and the increase in the said areas of invasive vegetation such as the *Prosopis juiliflora*, an 'alien' plant introduced a few decades ago, which is not eaten by the goats and other domestic animals.

It is clearly not possible to ask the local population to give up this resource (which together with fishing is their main source of sustenance), nor even to reduce its number, either at the present or in the future, but perhaps it is worth trying to change or redirect some established customs which are harmful to both humans and the environment.

The aim of this project is therefore the establishment of areas capable of producing fodder so as to satisfy the needs of the livestock, especially during periods of drought. A livestock which is used to eating anything, including thorny bushes and the bark of trees. This vegetable mass could initially constitute a sort of reserve to be used during periods of drought, when food is more scarce, to eventually, by expanding the arable land, become a permanent source of fodder, although clearly not a substitute for the natural grazing areas that during the rainy season grow an adequate herbaceous layer.

This availability of vegetation could eventually stop or slow-down grazing inside the oasis and the felling of trees, thus decreasing pressure on the ecosystem, allowing it to self-regenerate, resulting in undeniable advantages for the containment of erosion and desertification.

The chosen area is situated next to the landing strip to the west, still used for wild grazing, and is characterised by the substantial loss of the herbaceous layer due to excess grazing and erosion; it is a no-man's land, outside of the urban centre yet adjacent to it and far from the oasis. It is crossed by the path that connects the village of the El Molo to the Desert Museum built by the Italians[9].

In this area the salinity of the soil is high and lacks in nutrients, is exposed to strong winds and there are no water sources nearby, so it was decided to experiment with the cultivation of a non autochthonous plant that can guarantee a plant mass that can grow in particularly difficult conditions and which needs little maintenance: the *Vetiveria zizanioides Linn.,* or Khas.

It is a perennial herbaceous plant of the family of the *Poaceae* originally from India and Sri Lanka, but which grows spontaneously also in tropical areas of Western Africa (Sierra Leone) and used in the region between Senegal and Nigeria, caespitose and sterile, absolutely not infesting, and which does not produce stolons or rhizomes[10] (it grows only by planting rhizomes and therefore there is no risk of

Fig. 10 The old Nursery of the Nanyori Group in Loiyangalani. (Photo: L. Vallerini, 2008).

introducing another invasive 'alien' plant, like *Propospis juliflora*). It has a dense and fibrous root system, up to 5 metres deep, capable of consolidating the ground underneath, whereas the foliage forms a dense crown approximately up to 150cm high, which limits superficial erosion. It adapts well to extreme pedoclimatic conditions, sodic, stony, clayey, and chalky soils, very hard and compact, it resists to direct sunlight at high temperatures and is extremely resistant both to drought and to complete immersion for long periods in water, as well as to high salinity; it is resistant also to fire and it does not suffer the attacks of fungi or insects.

It is very useful as raw material for producing paper and rope, mats, hats and baskets. The distilled roots are used in the production of substances for skin care and volatile oils (Vetiver oil) are extracted for the production of perfume and scents for soap. It is also used in infusions for fever, cold, pleurisy and yellow fever. The roots are also carried in clothes for its scent and as insect repellent. In some areas it is cultivated as a measure against malaria. The leaves, which unlike the roots have no scent, provide fodder for sheep and cows when they are tender, and at all times for goats.

These products can be combined in the future with those of the Palmerie and the *Afforestation* thus providing an additional source of food and opportunity for economic development[11].

Regarding the cultivation method, it is very simple. In our case, due to the need to produce a vegetable mass for feeding livestock[12], it will be a question simply of harvesting for fodder the aerial part of the plant, which will grow back in a short period of time.

This plant is generally capable of enhancing the fertility of the soil, thus favouring as well the regrowth of local herbaceous species.

It is necessary to water the plants during the phase of taking root, but once the plant has developed, it can provide for itself thanks to its very deep root system.

It is worth mentioning that Vetiveria has already been amply tested in Kenya in the District of West Pokot, precisely as a defense against erosion and desertification; with a combined programme (WWIDP) carried out in the years 1987-88 between the Kenyan and Italian governments, Vetiveria was used both as erosion control and animal food supply for the increase of agricultural production in some farms[13].

This confirms the choice of the use of this plant in our area as well.

Figg. 11-12 Public meeting in Loiyangalani organised by Nanyori Group. (Photo: P. Altemura, G. Ceccanti).

Area Project 4. Monitoring and Communication Centre – M&C Centre, New Nursery, Compost Plant

As amply mentioned in the previous chapters, an important role in the carrying out of interventions against desertification (management of the Nursery, selection and cultivation of plants that are adequate for the conditions in the area, planting of trees in collaboration with the various ethnic groups present, etc.) was played, and still is, by the local CBO, the 'Nanyori Group'.

This is a group of volunteers that has supported the entire survey phase carried out by the Turkana Scientific Research Group in August, 2008, both pointing out relevant issues and problems, and gathering material and documentation as well as providing support in the relationship with the local population and authorities and organising public meetings during which the aims of the project were expounded and advice, as well as individual or collective issues, were heard.

The Nanyori Group has thus been involved in the project and part of the interventions from the outset, and will certainly be key to the success of the project as a whole, not so much from the technical-applicative point of view, but due to its role as an 'intermediary' with the four ethnic groups (Turkana, Samburu, Rendile and El Molo), all of which have representatives in the Group, and as contact with the local administration.

The Nanyori Group had initiated some time back cultivation practices and techniques for the on site production of plants which were then transplanted on a regular basis to various areas of Loiyangalani with some degree of success; so in a way it was only necessary to increase the cognitive and operative capacities of the Group, both from the technical-scientific and organisational point of view, and through the supply of tools and materials for the cultivation of the plants, for increasing the fertility of the soil, and providing the Group with I.T. and communication equipment.

In August of 2008, the Nanyori Group was relocating its Nursery from a 'central' area to a more 'peripheral' area of recent urban development, larger than the existing one (which was rented) and, especially, that had been offered to them by the community from its common land. They were carrying out this relocation and expansion of the Nursery, including fencing it in and building a logistical structure in the almost no funds at all.

The aim of this project was thus, on the one hand, to offer material help to the Nanyori Group in terms of logistics, and on the other in the expansion of their functions and services aimed at the undertaking of projects and increasing their technical skills both in agronomic-botanical and information technology terms, through interventions on the training of their personnel as a part of the previously mentioned Tutoring and Training programme initiated in collaboration with the Baraka Agricultural College of Nakuru from February to December, 2017.

The strengthening and consolidation of this local CBO is the basis for the success of the project in the short-medium terms (carrying out of interventions), but especially in the medium-long terms, when outside support will be reduced and the development of the oasis system will be in the hands of those who live in it.

Fig. 13 The new location for the M&C Centre, Nursery and Compost plant before interventions. (Photo: L. Vallerini, 2011).

The area of intervention, as said before, belongs to the Nanyori Group and lies to the west of the village of the Turkana, in an area of dynamic urban development, in other words in a mixed are including both traditional dwellings and new tin roof shacks, and adjacent to a much used public water fountain.

The soils are characterised by early-stage formation processes, that do not show degradation[14], although having scarce, and often absent, vegetation layers (indiscriminate felling of pre-existing acacias in natural scattered formations). Although presenting serious edaphic limitations (low hydric retention capacity, or AWC[15], excessive drainage and very low concentration of nutrients), the continuation of the programme of planting urban trees and providing support watering by the local community has given positive results. The use of compost, the production of which is envisaged as a part of the activities of the new center, added to each tree at the moment of planting, will ensure a greater success of growth and an increase in green biomass in the complex landscapes of the oasis (understood as a whole).

The interventions envisaged regard the creation of a centre for the production of plants to be eventually transplanted throughout the entire oasis, for the management of all envisaged interventions in other areas (well and distribution system, palm grove, afforestation, vetiver area).

In fact, the construction of this centre should constitute the 'motor' of the reconstruction of the oasis and be the reference and meeting point for the inhabitants of Loiyangalani and for the villages of the El Molo, with the main objective of disseminating the 'culture', also in scientific terms, of the intervention as a whole, of expanding technical skills for the cultivation of the palm grove and of the other areas, as well as for the production and sale of the products and the increase of economic resources, etc.

The works undertaken at the centre are a new building II M&C Centre, the new Nursery and the Compost plant; all of which has been fenced-in using the *Marara* system for its protection from weather conditions, humans and animals, and from direct sunlight with a large wooden arbor covered with *Makuti.*

An important role is played by the system of technological equipment. Photovoltaic panels and battery accumulators guarantee electricity both day and night for lighting, both inside and outside the centre, as well as for the good functioning of computers and other devices, while the hydraulic system taps into the public water fountain which provides water twenty-four hours per day, thus allowing to water the plants in the Nursery and to have running water and toilets, and finally, also an underground sewage treatment system which prevents from polluting the surrounding areas.

The executive projects and their realisation

Whereas the *Feasibility Project* constituted the cognitive base for understanding what to do and how to operate, and subsequently to obtain funds from the EU, the *Detailed Projects* (see the complete list next to the Index) were essential for working in detail on the interventions, to adjust the aim on more feasible objectives, also in economic terms, and to understand which solutions to adopt in relation to increasingly more specific requests, and to the results of the many meetings with the local community.

Additionally, the executive projects were essential for the drafting of the estimate metric computations, or Bill of Quantities - BOQ, and of

Fig. 14 The area for interventions of the Palmeraie and Afforestation near the Secondary School and the Police Station. (Photo: P. Magazzini).

the terms and conditions for the tender procedures concerning the assignation of works to be undertaken by the various companies or for calculating the labour and materials necessary for the works carried out by the local inhabitants with the participation of workers, both *skilled* (masons, carpenters, etc.) and *unskilled* (casuals).

In fact, while for some jobs, such as the construction of the building, the drilling of the well, the construction of the irrigation canals or the installation of technological equipment it was necessary to call for tenders in order to hire the companies with the technological capacity to actually carrying out the work, in the case of many other jobs, such as the *Marara* fencing, digging, carpentry, etc., it was possible to involve locals (casuals) which, under the guidance of skilled masons and so on, were able to work on the project, learn about it, and earn wages.

An important role in this phase was carried out by the offices in Nairobi and Marsabit of VSF-G (leading partner of the group that was awarded funds by the EU) and by the operative centre of the WRF especially established in Loiyangalani for monitoring the work and activities concerning information-awareness and tutoring-training, and consisting of a Project Manager, a Field Officer and Clerk.

Obviously, given the remote location of the area, the supply of materials, often even of the most elementary kind, the transportation of machinery, or finding companies willing to work in Loiyangalani, was not always easy, despite the fact that the choice of work techniques and methods were adapted as much as possible to the local know-how and capacities.

Following the partnership agreement between Vétérinaires sans Frontières Germany-VSF-G (Grantee) and the Water Right Foundation-WRF (Partner) of January 25, 2015 a series of missions were carried out by the experts of the scientific group for assessing the results of the Feasibility Project and the necessary detailed surveys concerning the territory in question and the five areas of intervention in order to draft the executive projects and begin with the work.

The contents of the Detailed Project concerned first of all the drafting of the detailed surveys of the four areas of intervention and the design of the fences and gates for the enclosure of the areas with the purpose of obtaining material possession of them and to affix the information notices for each area. The project (January 2016) of the 'temporary fences' made with barbed wire and wooden stakes was in fact the first step in the process of fencing-in the areas, eventually completed with various 'dead log' ystems for protecting the areas and the vegetation from animals, the wind and the sun.

The second executive project concerned the area for the cultivation of Vetiveria in March 2016, the third, which took place in Juy 2016 concerned the well, the related works regarding water collection and distribution, as well as the construction of the M&C Centre, the Nursery and compost plant, and the fourth and last in January 2017, regarding the areas for the *Palmeraie* and *Afforestation*.

The various phases of the project followed a programme that gave precedence to the area devoted to the Vetiveria, in order to show the local population and the authorities that this plant, once it has grown, could be an efficient choice for providing fodder for livestock (this actually took place in the period between April and May, 2017, during the serious drought that had affected the entire region).

The second phase, which involved the well and the centre, marked the beginning of the necessary groundwork as well as for providing water and generating the conditions for the integration, informa-

Fig. 15 The M&C Centre under construction using local limestone for the walls. (Photo: L. Beninati).

tion, development and management of the areas where new vegetation has been planted.

The third, involving the palm grove and the new area with trees and shrubs, was the logical conclusion to the project and realisation processes which, as is always the case in environment and landscape projects, is the conclusive phase, that of plantations, following the completion of the necessary infrastructures.

The constructive phases were carried out following two systems. One concerns the determination of *Categories of Construction Works* and involves the quantification of the materials and work days (of both casuals and specialized workers) necessary for the execution of the interventions, directly supervised by VSF-G and WRF, and the other regards bidding processes for 'Typologies of works', inviting local operators and contractors through public tenders and then, once the winner-assignees have been chosen, with contracts whose annexes consist in the executive projects and relative metric calculations.

Work was carried on and successfully completed despite the obvious difficulties regarding the remote location of the area of intervention and the need to adapt to the know-how of the local population.

Endnotes

[1] United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, 1994-97.

[2] The *National Drought Management Authority* (NDMA) is a public body established by the *National Drought Management Authority Act* (NDMA) in 2016. The history of Kenya's work on drought management goes back to 1985, with the design of a drought contingency planning system in Turkana. In the early 1990s this system was extended to other 28 arid and semi-arid districts, now 23 Counties where the NDMA has established offices.

[3] UNCCD 2005, *Promotion of Traditional Knowledge. A compilation of Documents and Reports from 1997-2003*, Bonn, Germany.

[4] Langill S., Ndathi A. J. N. 1998, *Indigenous Knowledge of Desertification. A progress report from the Desert Margins Program in Kenya*.

[5] County Government of Marsabit, Dpt. Of Administration, Coordination and ICT, Laisamis Sub-County, Loyiangalani Ward, 2015, *Allocation for Nanyori CBO and Water Right Foundation for Protection of Activity Areas*, Ind. 01, vol. 01.

Fig. 16 Members of the research team during the surveys at Koobi Fora. (Photo: L. Vallerini).

[6] The El Molo are the original inhabitants of the area. They are a fishing community who live in total isolation along the shores of lake Turkana and have no source of good, drinkable water, since the water of the lake is unsafe for human use due to the high concentration of fluorides and of some heavy metals, among which iron and manganese. The use of this water for drinking by the ethnic group, which is currently at risk of extintion, has caused the development of many ilnesses, especially of the skeletal system, as well as diseases linked to organic pollutants.

[7] Laureano P. 1995, *La piramide rovesciata. Il modello dell'oasi per il pianeta Terra*, Bollati Boringhieri Ed., Torino.

[8] In Kenya as in other countries, during Ramadan, following tradition and also because that is what the Prophet himself did, Muslims break their fast at the end of the day by eating dates and drinking water. Since it is not a large producer of dates, Kenya has to import vast quantities from other countries.

[9] The Desert Museum, inaugurated 2008, and designed and built with funds from the Italian Ministry of Foreign Affairs, is located on a hill over the lake to the north of Loiyangalani. The museum presents cultural elements from the local ethnic groups as well as historical and environmental aspects concerning the area of lake Turkana. It is run by the National Museum of Kenya, which organises every May in Loiyangalani the Lake Turkana Festival, a cultural event lasting two weeks at which thousand of people gather from all over Kenya, Ethiopia, Uganda, etc.

[10] Royal Botanic Gardens, *Kew (K), Herbarium*.

[11] Singh G., Upadhayay R. K. 1993, *Vetiveria zizanioides (Linn.) Nash. A multipurpose eco-friendly grass of India*, «Proceedings of ICV-2», pp. 444-448.

[12] At the website of the *Vetiver Network International* the methods for feeding livestock (including cows and pigs) with fodder obtained from the Vetiveria. Available online at www.vetiver.org.

[13] Mugova A., Mavunga J. 2000, *WEI integrated development project: a success story in desertification control*, «Desertification Control Bulletin», no.36.

[14] In this area the soil is neither saline nor alkaline, with an almost neutral pH between 7 and 8, yet there is a lack in nutrients. These are areas almost completely excluded from phenomena of flooding due to the presence of mechanisms for the deviation of multi-course hydric systems, consisting of incoherent and gross to very gross granulometry, including pebbles and stones that reach sizes measurable in decimetres, whereas finer materials are dominated by sand and silt. These deposits generated scarcely evoluted soils from the pedogenetic point of view, yet deep enough for tree root systems, which find obstacles only in the excessive stacking of macropores or in the presence of rocks (in the case of very superficial deposits).

[15] AWC –*Available Water Capacity* is the range of hydric availability that a soil is both capable of storing and making available for the growth of vegetation.

Water

Search of water, a new borehole. (Photo: P. Magazzini).

The search for water and the new well

Detail of water from the well. (Photo: J. Nakhulo).

Fig. 1 Pole Dipole Array. Schema 2: Pseudo-section schema for Dipole-Dipole or Pole-Dipole Array. (By: M. Folini).

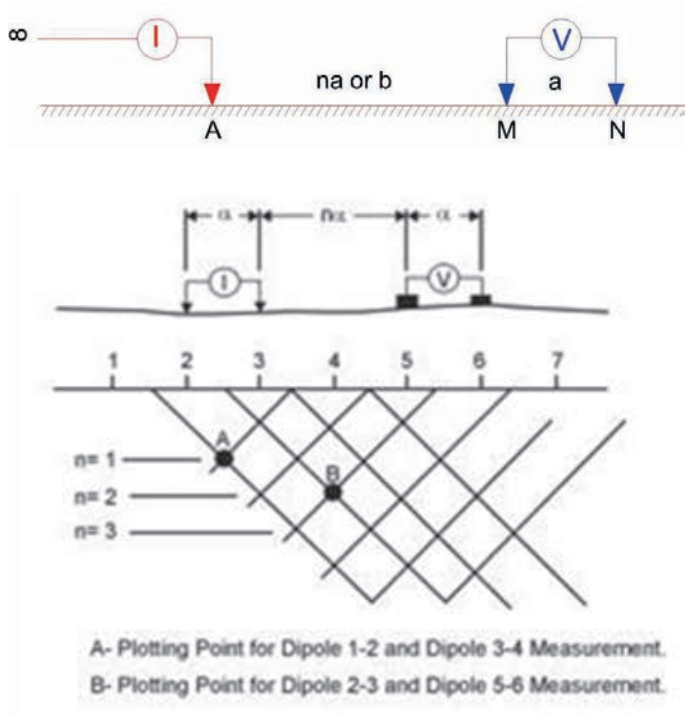
Marco Folini

The presence of water at shallow depths coming from thermomineral circulation systems excluded the need to drill wells which would have been more expensive and uncertain. For this reason, during the various missions, the gathering of data and samples from deep phreatic aquifers in order to directly determine their characteristics and productivity was not always possible.

In any case, since their potential was evident from the outset, an in-depth study was programmed using a rigorous research methodology, which, unfortunately, in these contexts is ultimately almost never used. Operating in this way it was possible to accurately determine the geometry of the deep structures and to acquire elements for understanding the two different mechanisms of refilling, thus setting the basis for a possible *governance* of the water resources: on the one hand for the identification of the sites and the establishment of new collection points, and on the other for the assessment of the vulnerability of the aquifers and the determination of the procedures for their maintenance and safeguarding.

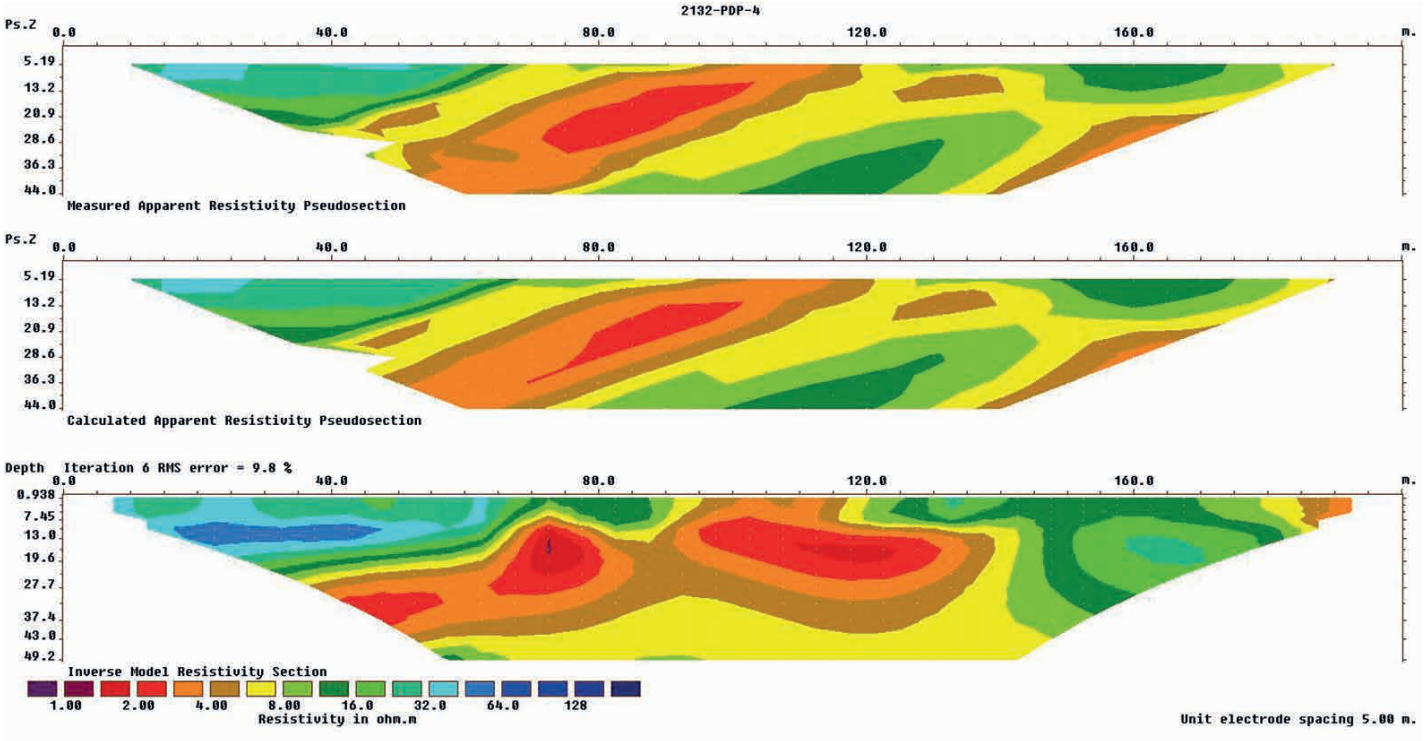
The preparation of a project of this nature was not possible without reconstructing the hydro-geological conditions of a wide context for which it was necessary, first of all, to obtain specific data on the geology and structural geology of the area derived from photo-interpretation, as well as specific information derived from geo-physical surveys, essential for reconstructing, at least locally, the structure of the the subsoil and for obtaining information regarding the thickness of the upper layers.

For this purpose a geoelectric survey technique was used, which allows identifying lithological successions based upon their electric resistivity. The system is based on the emission of electric currents through electrodes that are moved around the ground according to a predetermined schema and connected to a direct current generator and a control unit that measures the potential difference between emitting poles.



Processing of the obtained data allows a representation of the results in the form of a section of the subsoil (electric tomographies) through isovalues that determine the geological discontinuities identified by the survey. The graphic representation obtained by associating the acquired values to the chromatic scale is a bi-dimensional image of the subsoil, particularly efficient in terms of representation, understanding, and application. Representation in two dimensions permits reading the graph as an actual section of the subsoil in which the depth of the anomalies and the value of the electric parameter represented are real.

In the examined area two geo-physical campaigns were undertaken: one in February 2011 and the other in October 2016.



Loyiangalani

During the first campaign in 2011 two different areas were explored in the Turkana village through the performing of geo-electric tests in eight profiles using the pole-dipole technique (three in the area to the north – zone A, five in the area to the south – zone B) which permitted reconstructing the geometric layout of the alluvial deposits and identifying the potentially more productive locations for drilling a well in an area with gravel layers with a sufficient thickness and extension.

From the results obtained during the geo-physical survey, in proximity of the crossing of Lines 6 and 7, a relatively continuous presence of coarse gravel layer of considerable thikness was found at an approximate depth of 30-35 metres, therefore with good aquiferous features, separated from the surface of the ground by a layer of limey, more impervious material.

During the second campaign, in 2016, work was focused on the alignment of the springs along the eastern section of the oasis, following seven transverse profiles, also using the 'pole-dipole' technique.

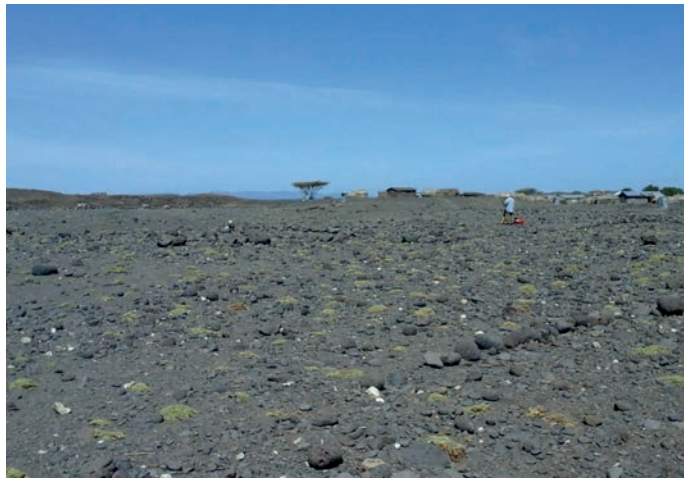
The results from these additional explorations permitted the definition of the stratigraphic and tectonic relationships between structures in this limited context, which helped understand the water circulation.

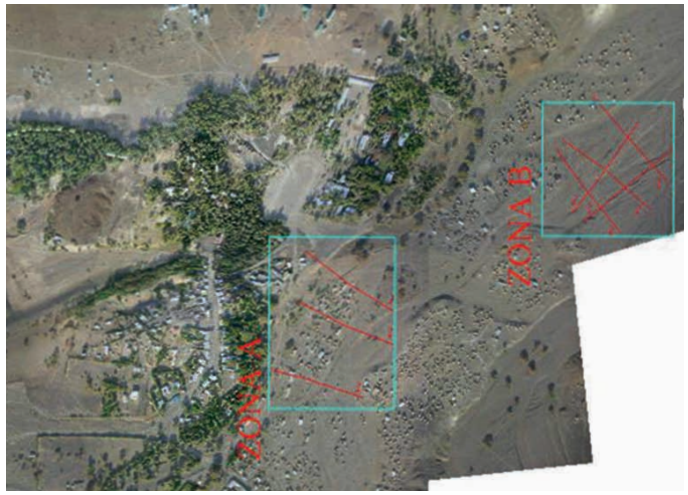
The basaltic boulders and volcanic layers that surface to the east of the oasis, characterised by a relatively high permeability, are in contact with lacustrine and fluvial lacustrine paleodeposits of lake Turkana, non-porous in depth due to their prevailingly clayey nature, but relatively more permeable at the surface due to the greater presence of lime and sand. This contact, whether stratigraphic or tectonic, permits the surfacing in the eastern section of water from the deeper artesian and semi-artesian aquifers.

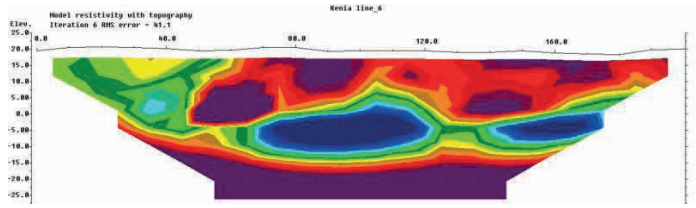
The explorations highlighted the presence of a resistive zone in the area of basaltic lavas at the east side of every stringing and of a conductive zone in the area with lacustrine clays to the west side of every stringing, deeper below the surface.

Based upon this stratigraphic-structural model, the springs along the alignment show the presence of a relatively articulated aquifer system within which the mixing takes place of the cold fresh water coming from superficial aquifer, which is supplied by the drainage network from Mount Kulal, and warm water coming from the deep geothermal circuit.

Fig. 2 Example of processing results. (By M. Folini).







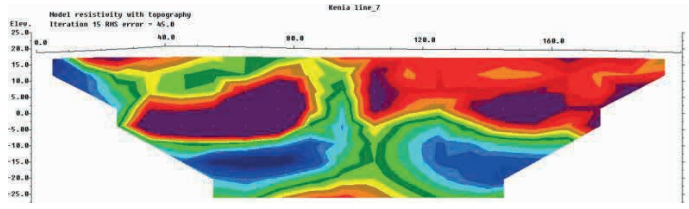


Fig. 3 View of the explored area in Loiyangalani and of the zone where the well is located. (Photo: M. Folini).

Fig. 4 Location of stringing. (Photo: M. Folini).

Fig. 5 Most representative stringing. (Photo: M. Folini).

El Molo

During the 2016 campaign a wide area with alluvial cone deposits was discovered to the east of the village, of which three profiles were explored, using the same technique described in the previous paragraphs.

In this case superficial gravelly and sandy soil was found, characterised by extremely low values of resistivity explained by the presence of salt water derived from the thermomineral springs situated to the east of the area explored.

Only in the central part of profile 6 was a slightly higher level of the values measured recorded, which permits supposing the existence of a structural height of the rocky substratum or of a plume of fresh water within the aquifer.

Results

In the presence of a spring one is fascinated by the manifestation of life directly from the depths of the Earth, and this phenomenon is particularly evident when the environmental context in which it appears is extreme. This is precisely the case of the boundless desert plains surrounding lake Turkana, where the presence of specific environmental conditions allowed the oasis of Loiyangalani to develop along a springs alignment even more special because of their thermomineral nature.

Since the first study missions it was clear how important it was not to alter the delicate balance of the oasis which, in a particularly hostile environment, represents a precious haven of life for thousands of people.

In view of this, the research carried out on various occasions between 2010 and 2016 were specifically aimed at reconstructing the deep hydric circulation mechanisms through interventions that would be as little invasive and risky as possible for the thermomineral circuit. It was possible to obtain a first hydrogeological overview and to identify the optimal location for drilling the wells envisaged by the project, setting the bases for moving in the direction of a correct and conscious management of the hydric resources available.

The conditions were created for aiming the search for new wells at the locations that were more appropriate for tapping into the most superficial aquifers of the water catchment area of Mount Kulal, along the drainage network of the *wadi*, potentially very interesting

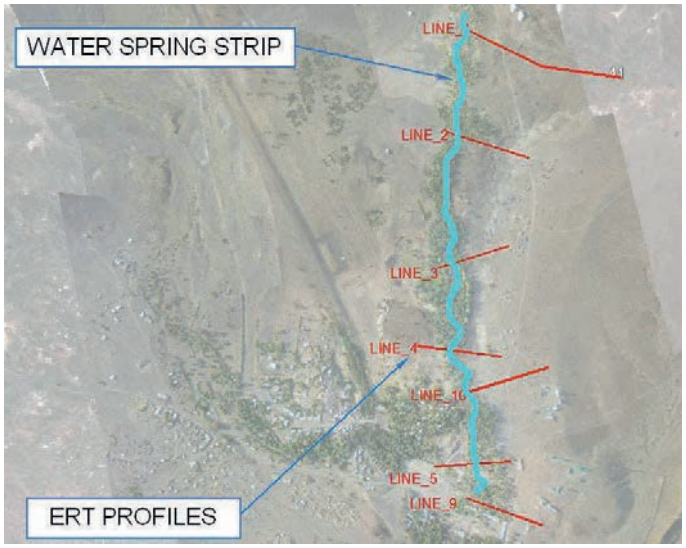


Fig. 6 Alignment of the springs in Loiyangalani and geoelectric profiles. (Photo: M. Folini).

Fig. 7 Profile carried out near the main spring in Loiyangalani (Line 10). (Photo: M. Folini).

Fig. 8 Source derived from the contact between lacustrine paleodeposits and volcanic layers. (Photo: M. Folini).

but to this day mostly unexplored, which could contribute locally to alleviate the weight derived from the need for water supply at an excessive distance from the villages.

After overcoming many difficulties of a logistic and technical nature, the well was finally drilled in the Turkana Village, in the locality of *Kula Mawe*.

Its most noteworthy features are:

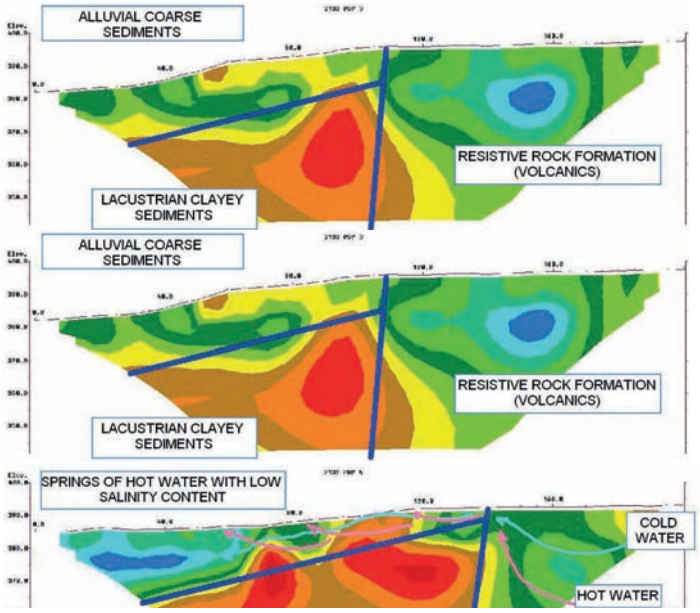
- diameter of the hole = 300mm;
- diameter of the pipe = 170mm;
- filters placed at a depth of 24 to 36 metres;
- cementing from the ground level to a depth of 21 metres.

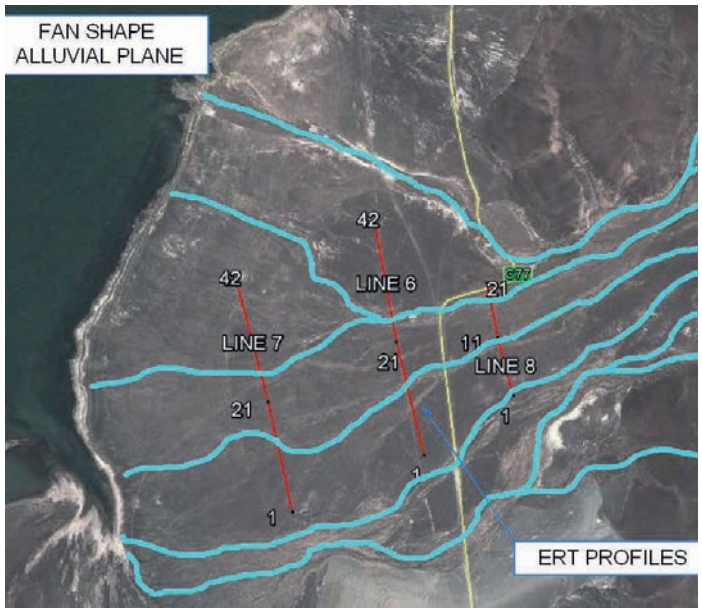
The volumetric and altimetric surveys carried out during the drilling process confirmed the hydro-geological model based on the research which, as mentioned earlier, was undertaken on several occasions during different phases and which in turn was based on satellite images, geological and chemical-physical surface surveys, and geo-electric tests.

The positioning of the filters and the great depth of cementing were determined by the need to maximise the isolation of the aquifer that was reached and to ensure the greatest possible protection of the groundwater from a qualitative point of view. The well was equipped with a submersible pump powered by solar panels placed on the roof of the two 5,000 litre tanks which are connected to the public fountain that is currently being built.

Pumping tests quantified the productivity of the well at about 1 litre/second and the first quick analyses determined a good organoleptic quality of the water, characterised by a relatively low conductivity level and a salinity level (890 mS) that is acceptable for drinking purposes. Also the temperature, at 38°C, is a physical measure that is useful for the study of the hydro-geological characteristics of the aquifer and for the reconstruction of the groundwater flow, in which the temperature usually varies from 13 to 18°C. Considering that beyond a depth of 30-40 metres the temperatures can be influenced only by the geothermal gradient, the temperature obtained probably means that there is either an exchange between the phreatic aquifer fed by the Mount Kulal Basin and the thermal water table that feeds the springs in the oasis, or else a thermal interaction with the rocks of the reservoir.

More in depth chemical analyses will permit to obtain further infor-





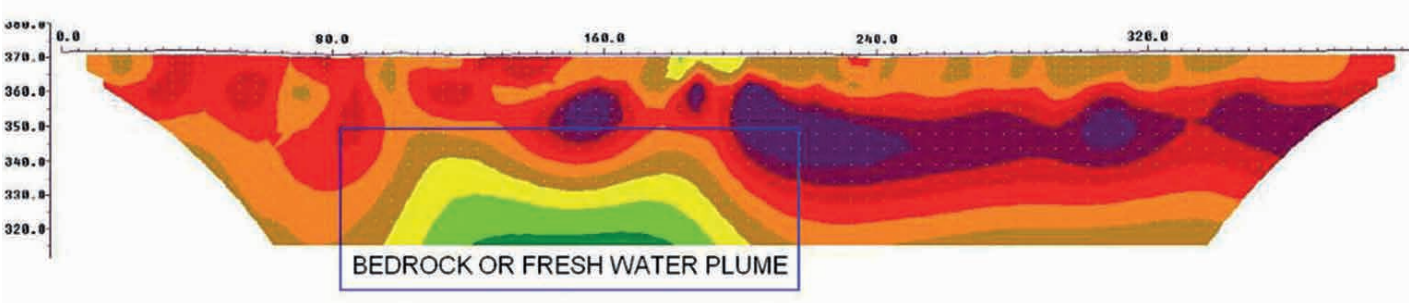


Fig. 9 Interpretation of lines 3 and 4. (Photo: M. Folini).

Fig. 10 Probable schema of hydric circulation in the proximity of the springs. (Photo: M. Folini).

Fig. 11 El Molo area: main conoid and location of stringings. (Photo: M. Folini).

Fig. 12 Results from Profile no.6. (Photo: M. Folini).

mation considering this very interesting aspect which is also important for determining the underground flows and to consequently establish the correct management of the water resources and its safeguarding from a qualitative point of view.

The well, being located in a *wadi*, was sealed on the surface and additionally protected by a double set of walls so as to avoid damages during floods. In the same way, the solar panels and the electrical system, which originally had been placed on a nearby trellis, were relocated to the roof of the two water tanks, which in turn were placed on a higher platform supported by gabions that were built as protection against erosion caused by the river.

Considering that pumping can be done only during the daytime, the water that it is possible to extract with this equipment permits filling the two tanks every three hours, thus ensuring a water availability of 20-25.000L/day, which corresponds to approximately 40-60 L/day per family.


KAV 491M

Fig. 13 Profile in El Molo area (Line 6). (Photo: M. Folini).

Fig. 14 General view of Loiyangalani with Mount Kulal in the background. (Photo: M. Folini).

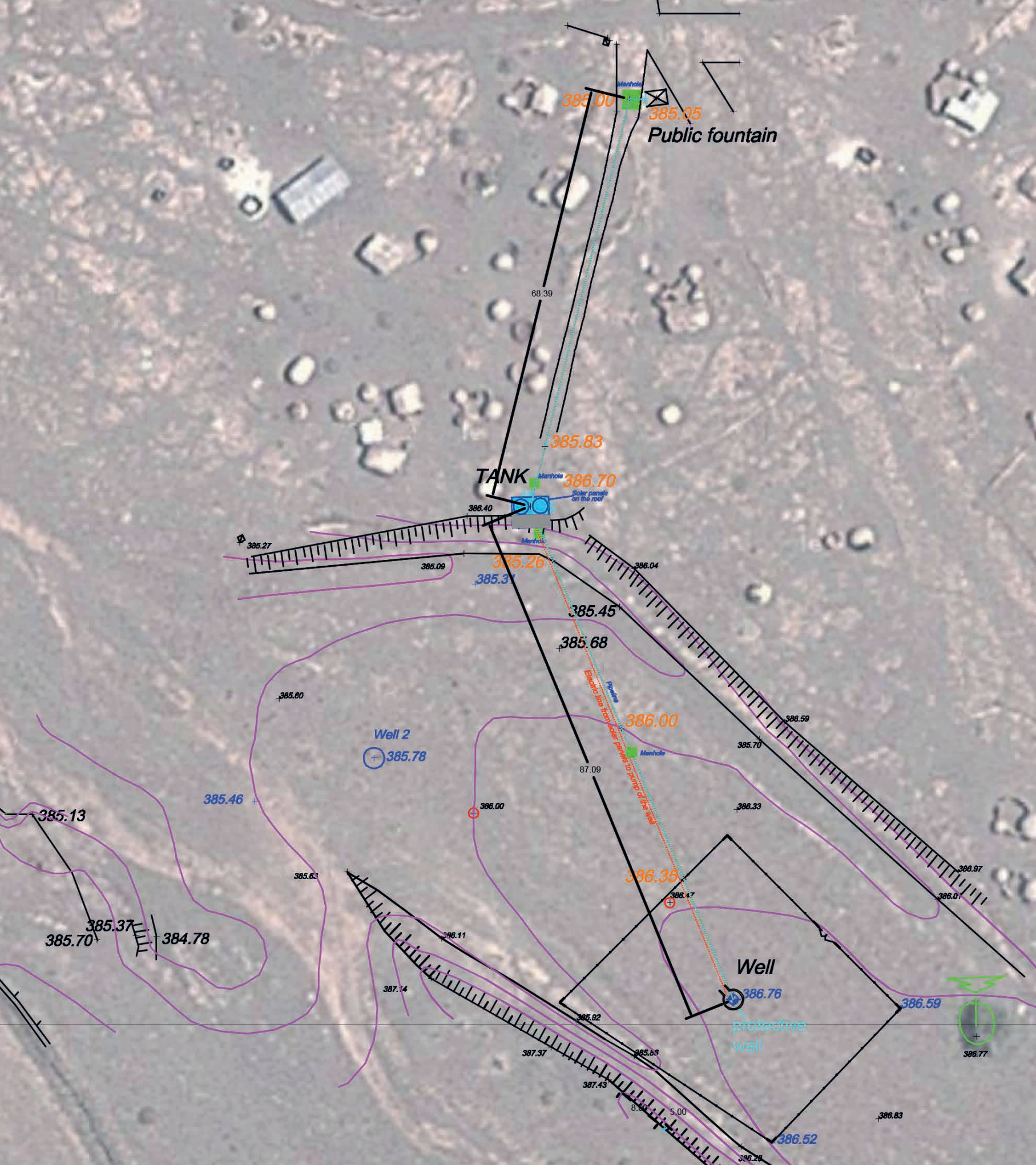
Fig. 15 View of the 'head' of the well and of the first protection wall. (Photo: M. Folini).

Fig. 16 Water from the well before the completion of the public fountain. (Photo: M. Folini).

With these features, and considering the current conditions, an exploitation of the resource may be estimated potentially greater to that which was initially envisaged during the study phase, resulting in daily water availability for at least 3.000 to 3.500 people, thus extending the range of usage to a wider area (at least two additional kilometres) around the Turkana Village.

In view of a correct exploitation of the resource, the tanks and the public fountain were provided with faucets so as to prevent waste and leakage and especially for generating awareness concerning the proper use of water in the local population. Following this same principle, the best methods for preserving the resource were indicated, both concerning the prevention of superficial pollution (the location of latrines, various types of spillage, indiscriminate grazing, etc.) and the correct usage (monitoring over periods of time, turning on and off of the pump, control of possible damages, conscious and aware usage of the resource, etc.).

In any case, if the extraordinary potentials of a unique area such as the oasis of Loiyangalani are to be preserved and valorised, it will be necessary to carry out further hydrogeological research that addresses the control of the flow rate and temperature of the springs and the study of the hydrological regime, the determination of the chemical and bacteriological characteristics of water and their variations through time, and the determination of the supplying hydrogeological basin. Only in this way can the project undertaken be completed.


385.00
385.05
Public fountain
68.39
385.83
TANK
386.70
Solar panels on the roof
386.40
385.27
385.09
385.26
385.31
386.04
385.45
385.68
385.60
Pipeline
Electric line from solar panels to pump of the well
386.00
386.59
385.70
Well 2
385.78
87.09
385.46
386.00
386.33
385.13
385.63
386.35
386.47
386.97
386.01
385.37
385.70
384.78
386.11
Well
386.76
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protective wall
387.14
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The use of the waters: the new Public Fountain for the Turkana village

Map of the water supply system. (Photo: L. Vallerini).

Fig. 1 Overflow water of the springs for irrigation uses in the Palmeraie area. (By L. Nofroni).

Marco Folini, Lorenzo Vallerini

In the region of lake Turkana annual rainfall amounts to approximately 210mm, mostly from the rainy seasons of April-May and November-December, and the high degree of evaporation caused by the high temperatures greatly reduces the amount of water available, also for the subsoil. However, the high elevations of the Kulal massif, favours more rain as a result of the warm and humid air coming from the lake. This rain flows down the western slope of the mountain to the area of the oasis of Loiyangalani during the rainy seasons under the riverbeds of the two *Wadi* (or *Laga* as they are locally known) to the north and south, with an east-west flow which through a series of springs along the main south-north branch of the oasis, provides a deeper and more constant supply of water throughout the year.

Basically, despite a difficult geographical context such as that of the entire region of the lake, Loiyangalani has enough water available for its needs throughout the year.

Unfortunately this resource is badly managed and poorly distributed. While the water from the two *Wadi* is not adequately used, the main springs are at risk due to organic pollution derived from latrines and from the new settlements located upstream. They are also often diverted for private use and in some cases channeled toward public fountains or directly used (also with the risk of organic pollution).

There are several public fountains available, yet they are not enough for the growing needs of the population. Two were built by the American Protestant Mission near the Safaricom antenna, in the most developed section of the settlement, another more recent one was built at the Malabo Resort, another two near the village of the Sam-

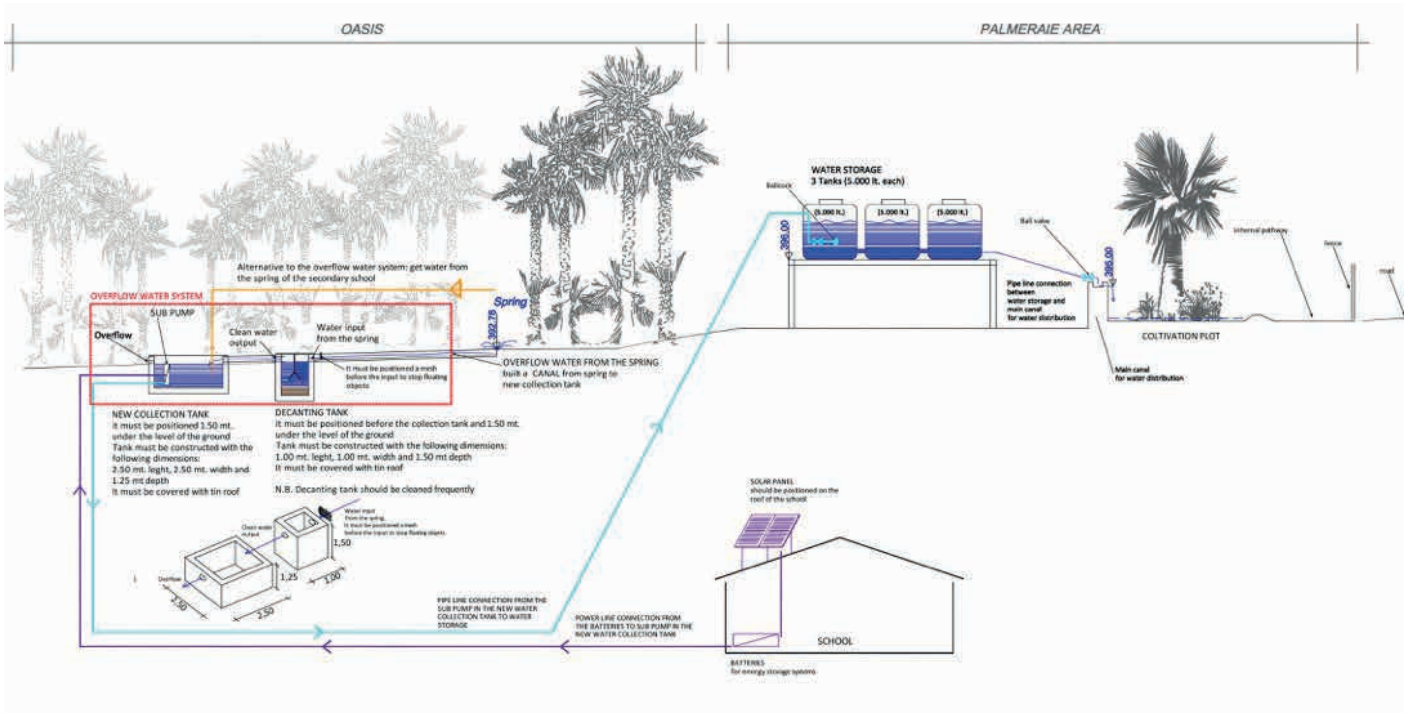
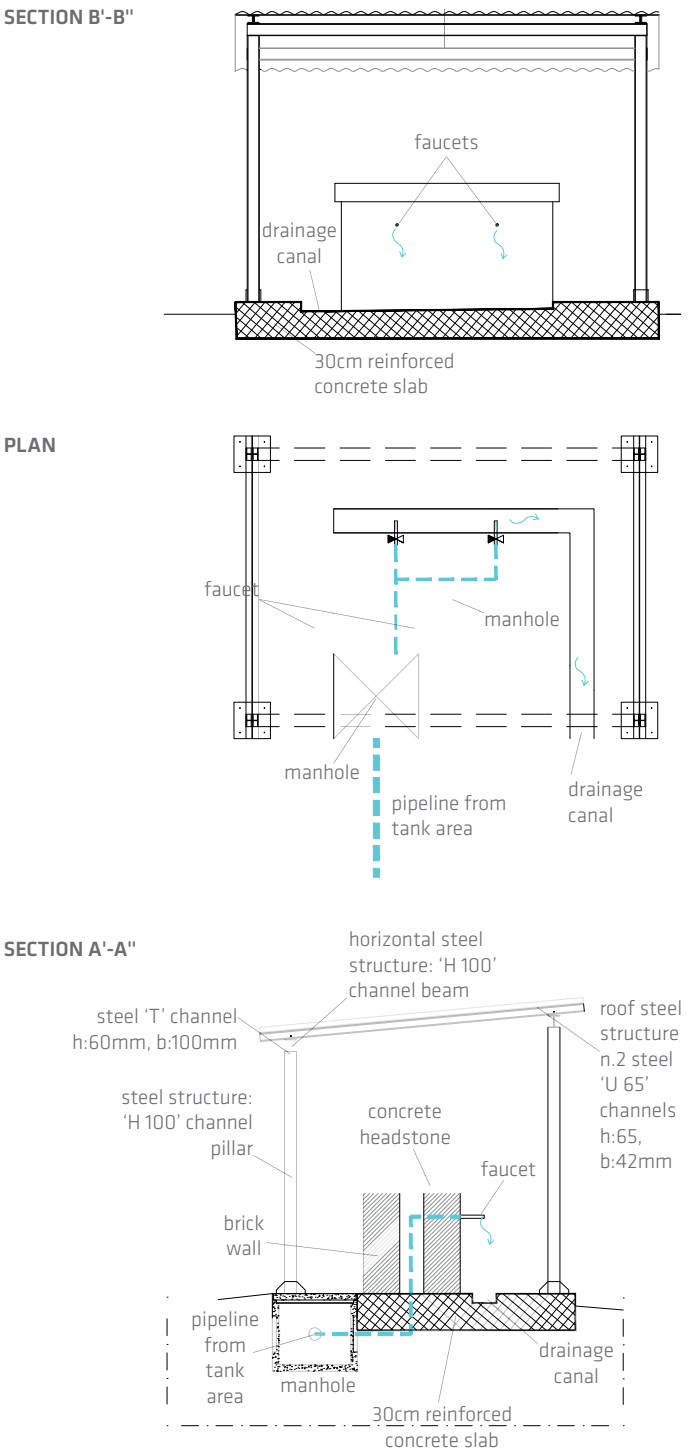


Fig. 2 Water tanks details. (By L. Vallerini).

Fig. 4 Protection of the escarpment of the wadi (or laga). (By L. Vallerini).

Fig. 5 Well construction and protection details. (By L. Vallerini).



buru and the Turkana, as well as other springs open to the public near the schools or inside the oasis.

The reason for the choice of the new well in the *Wadi* for supplying water from a source other than the springs was due on the one hand to the need to avoid additional water consumption from the springs, which are already widely used, and on the other in order to provide a supply point through a new public fountain to that section of the village of the Turkana which as yet had no access to water.

Solutions were sought to water needs that did not increase the level of consumption of water from the springs. Regarding the irrigation of the palmeraie and the afforestation areas, the *overflow water* from the springs in the oasis near the area of intervention has been identified as a source of supply.

By the construction of a catchment cavity made downstream of the springs, we can catch both the waters already being used and those that flow down without being used. These waters, although slightly polluted, are however adequate for irrigation, thus taking advantage of a resource that would be wasted.

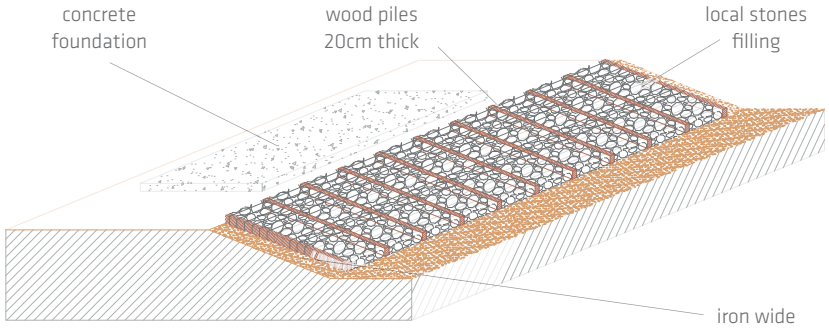
The building of the M&C Centre requires potable water, which can be obtained through a diversion (a T tubing connector) for filling the tank of the Centre from the public fountain during the night-time, when it is not used. This is also a good solution since the fountain is never closed, which causes a loss of water in its proximity (see photograph with a large puddle in the street).

Regarding the project for the well, it will be used as a source of drinking water and will be provided with a pump that permits collecting water in special tanks located at a higher elevation so as to allow the efficient distribution of water to the entire population.

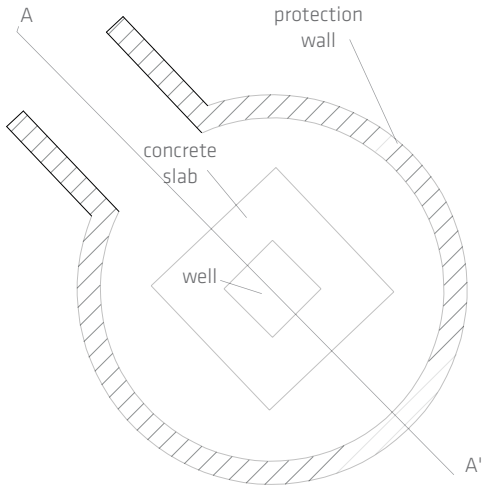
The solar-powered pump, with a hydraulic head of at least 40m, permits collecting water in two 5,000lt tanks placed on cement bases along and above the banks of the *Wadi* at a sufficient height to allow the supply by gravity to the public fountain.

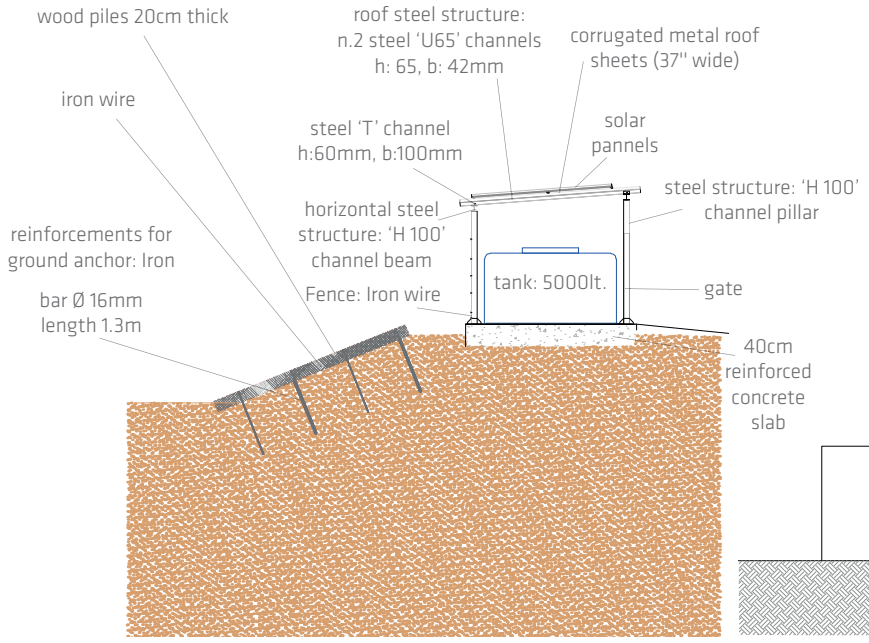
The tanks are built in cement and measured at least 6x3 metres; they also have a protective roof of the same size which is adequate for the installation of solar panels, whereas below them a protection system was built on the slope to avoid any undermining of the ground due to flooding. This protective structure consists of a series of poles anchored to the escarpment, covered with rocks and fastened with wire.

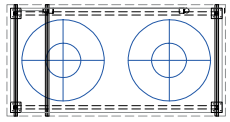
SLOPE PROTECTION SYSTEM



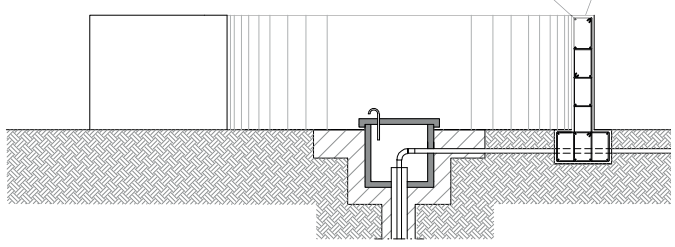
PLAN







SECTION A'-A''



Regarding the tubing that connects the well to the tanks, and in accordance to availability on the local market, approximately 90 metres of polyethylene pipes were acquired with a diameter of f=63mm, and installed at a depth of at least 50cm.

Since the intervention area is inside a *Wadi*, the area surrounding the well was protected by a fence and the adjacent area was additionally protected by a stone and cement wall approximately 100cm high, in order to avoid flooding during the rainy season.

Finally, the public fountain, placed at an adequate location for the village's needs in accordance with local representatives, was built using the same system that was used for the other fountains in the area: a cobbled cement platform with drainage canals (in order to avoid stagnant water) with a roof for protection from the sun. It is rectangular and has two faucets with gate valves strong enough to support heavy usage and to avoid any waste of water.

The maintenance of the supply system (well and equipment) and of the distribution of water (tubing, tanks, fountain) will be the test bed for this project, which has been designed with the sturdiest materials available, although it will be up to the local authorities and users to request and carry out all the necessary operations for its adequate functioning in the future.

Soil

Salty soil at Loiyangalani. (Photo: P. Magazzini).

The soil in Loiyangalani

Dry soil at Loiyangalani. (Photo: G. Ceccanti).

Lorenzo Vallerini

> In ancient Hebrew the term 'adamat', which indicates the soil, has the same root as 'Adam', the name of the first man. In the same way, the name of the firs woman, 'hava' (Eve in the transliteration) means 'living' or 'which gives life'. Thus put together, Adam and Eve mean 'the soil that gives life'[1].

The soil, as we have mentioned before, is an extremely dynamic system that plays a fundamental role in the survival of ecosystems and of human activity. The process of formation and regeneration of the soil is very slow, and thus is basically considered as a non-renewable resource.

The degradation of the soil constitutes a serious problem in many parts of the world due to a variety of causes, beginning with climatic change, but certainly often caused or aggravated by human activities, such as deforestation, inadequate agricultural practices, industrial activities, urban development, etc. The main forms of degradation are linked to erosion, the decrease in organic matter, salinisation, compaction, the decrease in biodiversity, loss of porosity, and floods.

The general scenario in arid and semi-arid zones is particularly critical, and the oasis of Loiyangalani and its surrounding belongs to this category – a typically arid environment with extremely prolonged periods without rainfall and constantly subjected to strong winds.

In fact, a good part of the soils in the area are characterised by serious levels of water erosion on the surface, caused by past events but which continue in the present and which have generated very saline soils due to the accumulation of materials including very soluble salts and sodium, together with a slow drainage system both during and after the rains.

In the section on 'Studies and Research' devoted to the analysis and survey of the soil in Loiyangalani over an area of approximately 365 hectares, a situation was identified characterised by:

a | The basaltic hills landscape, which represents approximately 28% of the area surveyed, is situated mostly on the strips bordering the oasis, with extensive areas with rocks on the surface, large sections with coarse rocks and others with finer material. In fact these are soils without vegetation, even herbaceous or of small thorny bushes, yet with some Acacia trees toward the flatter zones. With the exception of these flatter zones, where it can be envisaged to establish tree and brush vegetation that can adapt to scarce humidity and depth, in the remaining areas it is extremely difficult, if not impossible to develop any vegetation.

b | Ancient lacustrine deposit landscape, which represents approximately 22% of the area of the oasis, the landing strip and the surrounding areas; in these areas the soil is usually more clayey with less skeletal content and less stoniness on the surface, but on the other hand, they have a larger level of soluble salts and a higher degree of alkalinity, as well as a low content in organic substance and fertilizing elements. These, however, are soils that are already partially covered in vegetation (Doum Palm) which, except in specific cases, when adequately managed have the potential of supporting additional and new tree, brush and herbaceous vegetation with both productive and ecosystem reconstructive functions.

c | Alluvial terraces and current 'wadi' landscape (Laga)[2], which represent approximately 50% of the surveyed area, are the flood-lands and the riverbeds of seasonal watercourses, active only during the rainy season, and located to the south and north of the oasis, with soils characterised mostly by coarser materials, including pebbles and stones, but also finer materials, such as sand and gravel. In more elevated sections the risk of flooding is almost completely nonexistent. These are generally soils with a low salinity on which herbaceous vegetation grows, as well as groups of Doum Palm, and which can be used for the cultivation of herbaceous and brush vegetation.

Fig. 1 The lava landscape in the inner areas around the lake. (Photo: L. Vallerini).

The interventions envisaged by the project for bettering the soil, or else for halting its degradation, are obviously linked to the expansion of the layer of vegetation, or topsoil, in accordance with the characteristics of the soil.

This decisive intervention of an area-ecosystem type is not limited to single tree plantations, as in the case of the urban trees currently being planted by the community, which are certainly useful and important as well for generating awareness among the local community, but with limited effects concerning the actual recovery and expansion of the oasis.

Together with the new plantations (experimental pasture-fodder areas with Vetiveria, date palm-fruit tree-orchard and reforestation area) other interventions are aimed at providing protection from the strong winds in the most exposed sections and for increasing the fertility of the soil through the use of compost produced in the nursery, as well as experimenting with area (non specific) irrigation systems.

The issue of excess grazing remains, as well as that of the indiscriminate felling of Acacias which have grown spontaneously in the area and of the general increase of population.

Endnotes

[1] Dazzi C. 2011, *Il World Soil Day e la percezione del suolo*, «La percezione del suolo», Atti del Workshop Giornata Mondiale del Suolo Palermo 2-3 dicembre 2010, Edizioni Le Penseur, Potenza.

[2] Wadi or Laga (in the local language) is the bed or valley of a stream in arid and semi-arid regions of southwestern Asia and northern Africa that is usually dry except during the rainy season.

Soil, vegetation and new cultivations in Loiyangalani

New Neem trees planting in urban area of Loiyangalani. (Photo: L. Vallerini).

Piero Magazzini

Among the objectives of the project a series of environmental interventions were envisaged with the purpose of halting the process of degradation of the oasis and recovering the vegetation layer where it has disappeared due to both natural and human-related causes.
The layer of vegetation of the oasis, whether herbaceous or arboreal, seems to have been considerably reduced over the past 10 years, with a tendency towards further contraction. The motives for this are basically linked to the increase in anthropic pressure which requires both more space for building dwellings, and more wood and greenery for food and fencing. This is further aggravated by the increasing sedentary life of shepherds, practicing grazing in the areas inside and surrounding the oasis during the entire year. The consequence of this is the shrinking of the existing tree species, especially due to the invasive nature of the doum palm and acacias, and the progressive disappearance of the herbaceous layer, which is already thin due to the aridity of the land.
The project proposes to intervene on three aspects linked to the recovery of the layer of vegetation in the oasis:

1. Establish new areas for grazing and fodder, also through the introduction of new, non-invasive herbaceous species
2. Create a nursery of herbaceous and tree species that can adapt to the climate and soil of the area to be used in different sections of the oasis
3. Rehabilitate the presence of trees in barren areas with tree and bush species, together with an irrigated productive date palm grove, and link ecological-plant rehabilitation actions with possible agricultural-productive activities.

The survey and mapping of the soils, described in the previous chapters, with the help of the data gathered on field, of the physical and chemical features of the soils and the climate, permitted the identification of 4 areas adequate for carrying out the interventions envisaged by the project.

The potentials and limitations of the soils were described for every area, which then allowed choosing the ideal plant species to be used. The Vetiver and Nursery pasture-grazing areas were located in the *'recent alluvial terraced landscape'*, while the areas for the productive tree-palm groves and conservative afforestation were located in the *'ancient lacustrine deposit landscape'.*
The characteristics of the soils and their potential, and the resulting appropriate choice of plants to be introduced, are presented below, with the exception of the nursery, where plants are grown in pots.

Vetiver Area | Experimental Pasture Area Rehabilitation
Recently terraced alluvial landscape
Soil Unit mapping 11
Soil profile: P5_2015
Soil Classification: Calcaric Fluvisols (Sodic, Alcalic) – WRB-FAO 2006

Location: The area for the experimental pasture rehabilitation is situated in the north section of the oasis, to the hydrographic left of the laga which flows in the north area of the oasis, on the most recent fluvial terrace, situated approximately 1-2 metres above the current riverbed.

Morphology: It is a prevailingly barren and eroded area, with a slight presence of superficial stoniness and traces of temporary flooding: a scattered grass cover is present, usually overgrazed by sheep and goats, as well as some doum palm bushes. This landscape is very common in the oasis, especially in the areas surrounding the urban settlements.

Soils: Soils are less developed, on recent alluvial deposits, with sandy loamy or loamy sand texture, many rock fragments (medium or

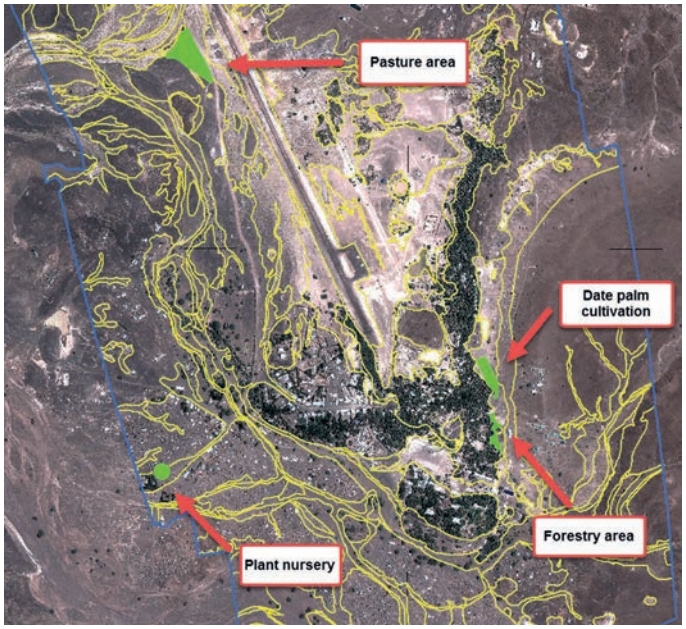


Fig. 1 Soil map (yellow lines) and, in green, the areas chosen for the 5 actions for rehabilitating the oasis. (By P. Magazzini).

coarse basaltic gravels) on surface and inside the profile. Structure is normally less developed or absent, soil reaction is still high, more than 9.0 and salinity on surface is low but increasing with depth. Alkalinity is high for the entire profile, up to 100cm from surface and organic matter content is weak or loose. Cation exchange capacity (CEC) is very low, so the fertility level is low.

Action: Recovery of sheep and goat grazing through the introduction of Vetiveria Zizanioides (alloctonous, non-invasive herbaceous species) in an area covering approximately 7,600m^2.
Vetiveria is largely saline and alkaline tolerant, sandy soils are good to develop Vetiveria, and the adult plants will offer good protection against soil erosion by flood and rain. At the adult stage the roots can penetrate up to the capillarity zone above the water table (about 3,0m deep) to provide water for growth.

Reasons for the choice: The choice of this area for the recovery of grazing land was made because of the following reasons:

- Flat surface, easily prepared by manual rock removing and surface levelling.
- The location of the area is close to the urban settlementeasily accessible due to the presence of a road alongside the area.
- Easy access to water for irrigation (using a 2,50m deep water well).
- Sandy soils, without rooting constraints, with low salinity and alkalinity levels and permanent humidity at 100cm below the surface.

PROFILE N. 5

Survey date: 04.10.2015
Coordinate: WGS84 UTMc7N 246002 306024
Site: Kenya, Loiyangalani, west air strip (Future Vetiveria cultivation area)
Elevation: 370m slm
Slope: almost flat
Land use: bare soil with diffuse grass pillows and rare doum palm shrubs
Vegetation: Grass pillows on sandy alluvial deposits
Morphology: Recent and actual alluvial flat plain
Rockiness: absent
Surface coarse fragments: frequent gravels and boulders
Surface runoff: excessively drained
Parent material: recent alluvial sandy and gravel deposits
Rooting depth: 100cm, limitation for abundant gravel and boulders over 100cm
Surface aspects: pastured
Erosion: Severe sheet and channel erosion
Water table: 3.0m - 3.5m deep
Soil Classification WRB 2006: Calcaric Fluvisols (Alcalic, Sodic)

A1	0-15cm; brown (10YR 4/3); biological activity: absent; rock fragments: common fine and medium gravel, subrounded; texture sandy loam; structure subangular blocky medium strong; slightly hard, very friable, non sticky, non plastic; reaction very highly alkaline; roots: many very fine subvertical; porosity common very fine; highly calcareous, lower boundary clear smooth.
A2	15-45cm; dark yellowish brown (10YR 4/4); biological activity: absent; rock fragments: many fine and medium gravel, subrounded; texture sandy loam; structure subangular blocky large moderate; slightly hard, very friable, non sticky, non plastic; reaction very highly alkaline; roots: common very fine subvertical; porosity common very fine; highly calcareous, lower boundary abrupt smooth.
2C1	45-60cm; pale yellowish brown (2.5Y 6/3); biological activity: absent; rock fragments: abundant fine and medium gravel, subrounded; texture loamy sand; structure single grain; loose, loose, non sticky, non plastic; reaction very highly alkaline; roots: few fine subvertical; porosity absent; calcareous, lower boundary abrupt smooth.
2C2	60-75cm; light brownish gray (2.5Y 6/2);); biological activity: absent; rock fragments: abundant medium and coarse gravel, subrounded; texture loamy sand; structure single grain; loose, loose, non sticky, non plastic; reaction very highly alkaline; roots: few fine subvertical; porosity absent; highly calcareous, lower boundary abrupt smooth.
2C3	75-100cm; pale yellowish brown (2.5Y 6/3);); biological activity: absent; rock fragments: many medium and coarse gravel, subrounded; texture sandy loam; structure single grain; loose, loose, non sticky, non plastic; reaction very highly alkaline; roots: common fine subvertical; porosity absent; highly calcareous, lower boundary abrupt smooth.
3C4	100-120cm and over, layer with abundant subrounded basaltic coarse gravel and cobbles in sandy matrix.

Fig. 2 Preparation of the surface of the area. (Photo: P. Magazzini).

Fig. 3 Detail of the experimental area for experimental pasture rehabilitation (2013 satellite image). (By: P. Magazzini).

Horizons:

Land suitability Vetiveria: S3 – marginally suitable with limitation for alkalinity and rock fragments.

Horizons	Very fine sand (0,05-0,10mm) (%)	Sand (2,0-0,05mm) (%)	Silt (0,05-0,002mm) (%)	Clay (<0,002mm) (%)	Textural class USDA	Reaction pH H2O 1:1	Electrical conductivity (2.5:1) dS/m
A1	30.0	58.0	38.0	4.0	FS	9.97	0.84
A2	29.0	56.0	35.0	10.0	FS	10.43	1.34
2C1	9.0	80.0	14.0	6.0	SF	10.24	1.02
2C2	10.0	74.0	20.0	6.0	SF	10.82	5.51
2C3	22.0	60.0	26.0	14.0	FS	10.78	5.74

Analysis:

Horizons	Gypsum Cmol/Kg	CaCO3 (%)	CEC (meq/100g)	Exchangeable Ca (meq/100g)	Exchangeable Mg (meq/100g)	Exchangeable Na (meq/100 g)	Exchangeable K (meq/100g)	ESP (%)	Organic carbon (g/Kg)
A1	0.08	7.5	3.5	1.50	0.46	0.90	0.63	25.7	0.02
A2	0.78	2.0	2.1	0.40	0.12	0.77	0.77	37.4	0.01
2C1	0.34	1.0	1.9	0.20	0.06	0.93	0.72	48.5	0.01
2C2	6.62	9.0	3.6	1.80	0.56	0.60	0.65	16.7	0.008
2C3	6.94	0.5	1.4	0.10	0.03	0.56	0.76	38.6	0.01

Date Palm Grove and Food Production

Ancient lacustrine deposits landscape

Soil Unit mapping 7

Soil profile: P1_2015

Soil Classification: Calcaric Cambisols (Sodic, Alcalic) – WRB-FAO 2006

Location: The area for the establishment of an experimental, irrigated, productive palm grove is located on a flat surface to the east of the oasis, near and above the strip with doum palm vegetation, near the main water sources of the oasis. The total surface of the project area is approximately 5600m^2 with an elevation of 393/394m slm.

Morphology: An almost flat surface established on an ancient terrace formed by fine fluvial lacustrine deposits covered by sub-recent gravel and sandy colluvial deposits. The western border is the oasis vegetated escarpment (Doum palm trees are dominant), where most part of the sources are located. To the east the area is limited by rounded eroded basaltic hills.

Soils: Soils in this area are moderately alkaline on the surface and increasing with depth, coarse textured (sandy loam), with basaltic coarse fragments in the first 30cm below the surface. Beyond 30cms this soil shows secondary calcium carbonate accumulation, the total calcium carbonate content being more than 20%. Soil structure is weak to massive, due to the effect on the clay structure of high exchangeable sodium content. The pH is high in all soil layers, more than 8.5, and the electrical conductivity is less than 4dS/m, so the soluble salt content is low. CEC is low in all soil layers related to the low clay content.

Action: Creation of an irrigated date palm grove with a permanent irrigation system and approximately 30 10x10m parcels with a date palm and 4 fruit trees and herbaceous or vegetables inside each parcel.

Fig. 4 Preparation of the area for the irrigated date palm grove. (Photo: P. Magazzini).

Fig. 5 Detail of the area where date palms were planted. (By: P. Magazzini).

Reasons for the choice: The choice of these areas for irrigated productive palm groves was due to the following reasons:

- Flat surface, with a slight sloping from the spring to the north, easily irrigable.
- Easy access due to the presence of secondary roads.
- Proximity to the main spring, whose surplus will be used to irrigate the palm grove.

Moderately developed sandy soils, with good water retention capacity, low salinity and moderately alkaline.

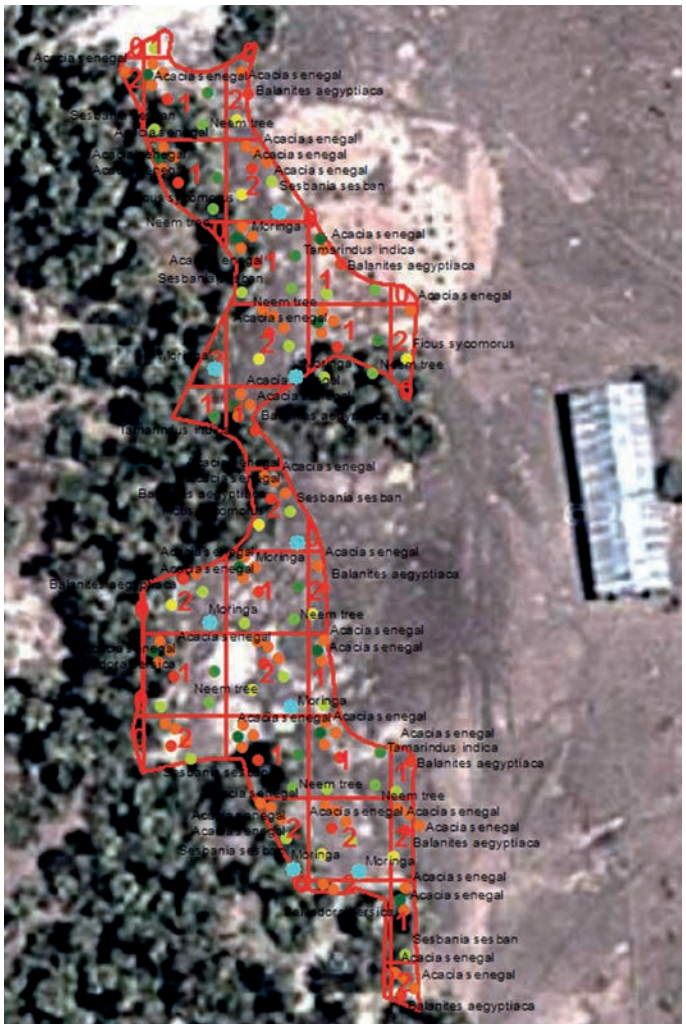
PROFILE N. 1

Date: 02.10.2015
Position: WGS84 UTMc7N 246924 305013
Site: Kenya, Loiyangalani, Down Police station
Elevation: 393m slm
Slope: almost flat
Land use: Bare soil with sparse grass pillow and severe overgrazing
Aspect: flat
Vegetation: Grass pillow on aeolian sand deposits
Physiography: Second order ancient fluvio lacustrine terrace
Rockiness: absent
Surface coarse fragments: abundant
Surface drainage: Moderately well drained
Substrate: Colluvial gravelly and sandy deposits on fine lacustrine sediments
Rooting depth: 105cm
Rooting limitation: High calcium carbonate content and abundant gravels
Surface aspects: weakly crust
Erosion: diffuse severe sheet erosion and gully erosion near the escarpment
Classification WRB 2006: Sodic Calcisols (Alcalic, carbonatic)

An1	0-10cm; brown (10YR 4/3); biological activity absent; coarse fragments few, fine subrounded basaltic; sandy loam texture, structure-less, consistence loose, non sticky, non plastic; reaction very highly alkaline; roots very fine common, pores common fine vacuolar, highly calcareous, clear wavy boundary.
An2	10-30cm; dark yellowish brown (10YR 4/4); sandy loam texture, coarse fragments few fine subangular basaltic; structure granular fine moderate, consistence loose, non sticky, non plastic; reaction very highly alkaline; roots common fine, pores few fine vacuolar; highly calcareous; abrupt smooth boundary.
2Ab	30-45cm; light yellowish brown (2.5Y 6/3); sandy loam texture; coarse fragments common coarse subrounded basaltic; structure subangular blocky medium moderate; few sticky, few plastic; reaction very highly alkaline; roots few medium, pores few very fine vacuolar; highly calcareous; carbonates masses common (fibers); abrupt wavy boundary.
2Bkn	45-60cm; light gray (2.5Y 7/2); sandy loam texture; coarse fragments very few cobbly subrounded basaltic; subangular blocky medium moderate structure to massive; few sticky, few plastic; reaction very highly alkaline; roots few medium; highly calcareous; c carbonates masses, many (fibers); pores very few very fine; l abrupt wavy boundary
2BCkn	60-105cm; light gray (5Y 7/2); sandy loam texture; coarse fragments very few cobbly subrounded basaltic; prismatic coarse strong structure to massive; few sticky and moderately plastic; reaction very highly alkaline; carbonates masses common (fibers); roots few medium; clear wavy boundary
2Ckn	120cm and beyond; silty horizon, hard with calcium carbonate accumulation; silty texture; coarse fragments absent, structure-less, massive; moderately plastic and moderately sticky; reaction very highly alkaline; no roots

Fig. 6 Aspect of the afforestation area before planting. (Photo: J. Nakhulo).

Fig. 7 Planting detail of the afforestation area. (By: P. Magazzini).



Horizons:

Horizons	Very fine sand (0,05-0,10mm) (%)	Sand (2,0-0,05mm) (%)	Silt (0,05-0,002mm) (%)	Clay (<0,002mm) (%)	Textural class USDA	Reaction pH H2O 1:1	Electrical conductivity (2.5:1) dS/m
An1/An2	31.0	64.0	34.0	2.0	LS	9.69	1.19
2Ab	32.0	60.0	40.0	0.0	LS	9.85	3.16
2Bkn	30.0	50.0	42.0	8.0	LS	9.36	2.82
2BCkn	29.0	64.0	28.0	10.0	LS	8.46	3.50
2Ckn	29.0	52.0	36.0	12.0	S	8.67	1.75

Analysis:

Horizons	Gypsum Cmol/Kg	CaCO3 (%)	CEC (meq/100g)	Exchangeable Ca (meq/100g)	Exchangeable Mg (meq/100 g)	Exchangeable Na (meq/100g)	Exchangeable K (meq/100g)	ESP (%)	Organic carbon (g/Kg)
An1/An2	0.57	24.0	9.0	4.80	1.43	1.97	0.80	21.9	0.02
2Ab	3.33	39.5	12.8	7.90	2.35	1.77	0.76	13.8	0.02
2Bkn	2.86	14.5	6.4	2.90	0.86	2.01	0.64	31.4	0.04
2BCkn	3.81	22.0	8.2	4.40	1.31	1.84	0.68	22.3	0.01
2Ckn	1.36	28.0	10.0	5.60	1.67	2.09	0.60	21.0	0.01

Afforestation: Rehabilitation and Conservation of the Oasis

Ancient lacustrine deposit landscape

Soil Unit mapping 7

Soil profile: P3_2015

Soil Classification: Calcaric Cambisols (Sodic, Alcalic) – WRB-FAO 2006

Location: The area for recovery and rehabilitation of trees is located on a flat surface on the eastern section of the oasis, along the irrigated palm grove, close to the doum palm vegetation strip and near the main springs of the oasis. The project area is approximately 3379m^2 on an almost flat surface with bare soils and sparse grass pillows growing on thin sandy aeolian sediments.

Morphology: Almost flat second order ancient fluvio lacustrine terrace below a basaltic hilly area and bordering a terrace vegetated escarpment. Severe sheet erosion. Bare soil with sparse herbaceous pillow and severe overgrazing. This land unit is diffuse mainly in the

Fig. 8 Date Palm planting in the Palmeraie area. (Photo: L. Vallerini).

eastern area of the oasis, representing an ancient silty fluvio-lacustrine terrace covered by a thin colluvial gravel sediment. All the area is severely eroded with diffuse sheet and channel erosion. Overgrazing by goats is the main cause of the disappearance of the grass layer.

Soils: Deep and moderately deep soils with an A-2Bw-2C profile, texture from moderately coarse (loamy sand) to moderately fine (clay loam), alkaline, calcareous, low salinity, however occasionally high on the surface. Diffuse rock fragments (medium or coarse basaltic gravels on surface. The soil structure is normally well developed, subangular, blocky. Medium cation exchange capacity (CEC).

Actions: Reforestation of a barren area using local plants which grow in the surroundings (Acacia Tortilis and Acacia senegal) and inside the oasis (Moringa, Sesbania, Neem Tree, Ficus, Tamarindus etc.), with the use of irrigation during the first planting stage and early growth phases.

Reasons for the choice: The choice of this area for establishing an irrigated productive palm grove was due to the following reasons:

- Flat surface, easy placement of forestry modules.
- Easy access due to the presence of secondary roads.
- Proximity to the main spring, with water availability for emergency irrigation.
- Moderately developed clayey soils, with good water retention capacity, moderately high salinity and moderate alkalinity.

PROFILE N. 3

Date: 02.10.2015
Coordinate: WGS84 UTMc7N 246938 304937
Location: Kenya, Loiyangalani, Down School
Elevation: 393m slm
Slope: almost flat
Land use: Bare soil with sparse grass pillow and severe overgrazing
Vegetation: Rare grass pillow on aeolian sand deposits
Morphology: Almost flat Fluvio lacustrine terrace
Rockiness: absent
Surface rock fragments: abundant fine and medium basaltic
Surface runoff: Moderately well drained
Substratum: Gravel colluvial deposits on silty fluvio lacustrine sediments
Rooting depth: 65cm
Rooting limitation: soil compaction
Surface aspects: Thin soil crust
Surface cracks: absent
Erosion: Severe sheet, rill and gully erosion)
Soil Classification WRB 2006: Calcaric Cambisols (Sodic, Alcalic)

A	0-25cm; Brown (10YR 4/3); biological activity absent; rock fragments fine and medium subrounded, basaltic; clay loam texture, subangular blocky structure, medium strong, moderately sticky, not plastic; reaction very highly alkaline; roots very few, very fine subvertical, pores few fine vacuolar, very calcareous, boundary clear smooth.
Bw	25-65cm; dark yellowish brown (10YR 4/4); clay loam texture, rock fragments few fine, subrounded basaltic; subangular blocky structure, large strong, very firm consistence, moderately sticky and plastic; reaction very highly alkaline; root commons medium subvertical, pores few fine vacuolar; very calcareous; boundary clear wavy.
C	65-120cm; pale brownish gray (2.5Y 6/2); clay loam texture; rock fragments absent; massive; moderately sticky and few plastic; reaction very highly alkaline; root few medium sub-horizontal, pores very few very fine vacuolar; very calcareous; organic matter and dead roots.

Horizons:

Horizons	**Very fine sand** (0,05-0,10mm) (%)	**Sand** (2,0-0,05mm) (%)	**Silt** (0,05-0,002mm) (%)	**Clay** (<0,002mm) (%)	**Textural class USDA**	**Reaction pH H2O 1:1**	**Electric conductivity** (2.5:1) dS/m
A	25.0	36.0	34	30	FA	10.66	10.66
Bw	14.0	36.0	26	38	FA	10.24	10.24
C	24.0	34.0	34	32	FA	9.64	9.64

Analysis:

Horizons	**Gypsum** Cmol/Kg	**CaCO3** (%)	**CEC** (meq/100g)	**Exchang. Ca** (meq/100g)	**Exchang. Mg** (meq/100g)	**Exchang. Na** (meq/100g)	**Exchang. K** (meq/100g)	**ESP** (%)	**Organic carbon** (g/Kg)
A	13.83	25.5	19.60	5.10	1.82	2.22	0.52	11.34	0.02
Bw	3.15	33.5	12.00	6.70	2.39	2.11	0.48	17.61	0.01
C	1.60	22.0	10.20	4.40	1.57	2.17	0.52	21.27	0.01

The fertility of the soil: Compost

Vegetable Garden in the Oasis.
(Photo: L. Vallerini).

Paolo Altemura, Marco Mazzoni

What is compost and how is it produced?

In a natural ecosystem, the organic matter derived from animal and plant residues is transformed by the action of microorganisms present in the ground, such as bacteria, fungi, algae and protozoa. These microorganisms decompose organic residues producing energy which they use in part for cellular anabolic activity, thus generating the proliferation of new organisms, and in part for transforming the substances present in the soil into stable organic compounds, among which Humic Acids. From the products derived from the activity of these microorganisms the so-called *Humus,* is formed. It provides nourishment for plants as a consequence of its capacity to bind, and at the same time to release important elements such as nitrogen, potassium and phosphorous, which are fundamental for the growth of plants.

Composting is a set of operations which help obtain in a brief span of time material which is rich in humus, nitrogen, potassium and phosphorous.

The composting process is a spontaneous, aerobic and exothermic process which, when correctly controlled, permits obtaining a stable product, free of pathogenic microorganisms and seeds from invasive plants, rich in humic compost which provides nutrients and enhances the soil.

Various species of aerobic microorganisms intervene, dominating on each other depending on the specific phase that is active at a given moment, in the composting process. The initial phase involves mostly mesophilic bacteria that degrade hydro-soluble compounds, which are also easy to metabolize, such as monosaccharides, aminoacids and organic acids. Exothermic processes give off heat which in rising the temperature favour the intervention of thermophilic bacteria that in turn carry out more exothermic decomposition reactions, bringing about a sudden increase in the temperature of the mass until reaching 60-65°C. At this temperature many of the harmful elements present in the material (pathogenic microorganisms, invasive seeds, etc.) are decomposed. Once their source of nourishment is reduced, also the amount of microbes shrinks, which results in a lowering of the temperature until it reaches a stable level. The metabolic processes diminish in intensity since they involve more complex organic molecules, among which starch and cellulose, which have slower degradation processes.

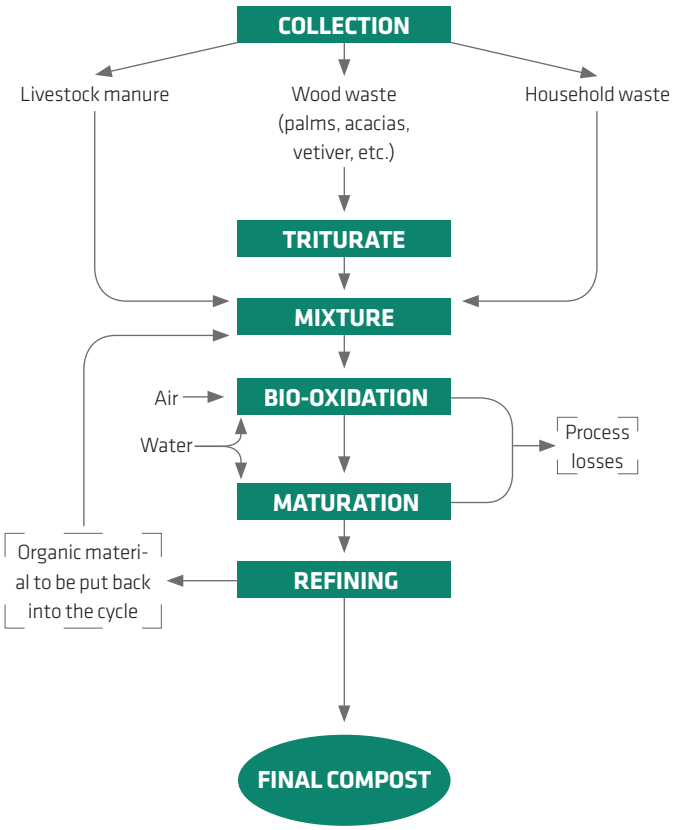
Once these processes have concluded, the original material has been 'bio-stabilized' and it is at this point that the colonisation of the organic matrix by protozoa and a variety of macrofauna begins. This community contributes to the process of maturing and humification of the original subsoil, bettering the final characteristics of the compost. In the advanced phase of the process of stabilisation of the macrofauna worms appear, such as Lumbricus terrestris, which have an important function in the quality of the compost as a fertiliser.

The composting process can be schematised into two main phases:

- bio-oxidation: in the presence of oxygen microorganisms degrade the immediately assimilatable organic fraction (saccharides, aminoacids, etc.) into simple compounds such as water, carbon dioxide and mineral salts, with an increase in temperature resulting from the chemical reactions which take place;
- maturing or humification: when the biological processes slow down and the temperatures begin to diminish because the most easily fermentable organic fraction has been consumed and the active microorganisms mutate. The process continues, bringing about the formation of humic substances.

The initial biomass suffers a reduction of the variable volume of between one fourth and half of the said volume, mostly due to the evaporation of water and the loss of carbon dioxide, as well as to the reduction in the size of the material.

The optimisation of the process, and therefore of the activity of the microorganisms, depends of the following factors:



- the correlation between Carbon/Nitrogen;
- degree of oxygenation;
- physical features (porosity of the material);
- degree of humidity;
- temperature;
- pH.

Correlation C/N

Carbon, nitrogen, phosphorous and potassium constitute the main sources of energy for microorganisms, and since they also constitute the main nutrients for plants, they also influence the agronomic value of a compost. The stabilising of the material that is undergoing a process of composting depends basically of the quantity of carbon and nitrogen in the biomass; in general microbial activity requires an amount of carbon that is 20 times superior to that of nitrogen. With C/N correlations that are lower to 20, carbon is entirely consumed without stabilising all the nitrogen present; on the contrary, C/N correlations that are greater than 40 require long composting times due to the excess in carbon.

Nitrogen

Nitrogen is fixed by microorganisms only if an adequate amount of carbon is available, otherwise the mineralisation of the nitrogenated organic compounds results in the release of ammonia; if the pH of the material is acid, it can turn into ammonium (NH_4^+), while alkaline conditions lead to the production of ammonia (NH_3); when the pH

Fig. 1 Dump near the Turkana village. (Photo: P. Altemura).

Fig. 2 Flow chart of the activities of the compost plant. (By: P. Altemura).

Fig. 3 Women returning to the Turkana village; each carries a bundle of firewood for cooking. (Photo: P. Altemura).

Fig. 4 Charcoal and firewood for cooking. (Photo: L. Vallerini).

Fig. 5 Women gather dry leaves and other vegetal materials. (Photo: L. Vallerini).

is alkaline the formation of ammonia (NH_3) is favoured also by the temperatures that are characteristic of the thermophile phase; the same conditions contribute to its dispersion into the atmosphere, resulting in the production of bad smells. In order to optimise the C/N ration in the initial mass it is often necessary to mix different types of biomasses.

Degree of oxygenation of the mass

Oxygen is necessary for the process of composting. The initial decomposition phase is characterised by the need of a large amount of oxygen, which then diminishes as the process develops toward the ripening phase. The concentration of oxygen for an optimal process should not be lower than 10%. If there is a lack of oxygenation anaerobic microorganisms take over which result in the production of malodorous and reduced amounts of compost (containing hydrogen sulphide and mercaptans) which is toxic for plants. In order to favour the oxygenation of the mass it is necessary that the substratum have a good degree of porosity, which is obtained through preventive grinding and mixing actions and through the aeration of the mass by periodically turning over the mass, especially during the first thermophilic phase. The ventilation of the substratum permits the dissipation of heat, the elimination of water vapour and of the various gasses present in the mass, yet should not bring about the total mineralisation of the organic substance, but rather the stabilising and humification of the original matter.

Physical features

The porosity of the substratum influences the maintenance of the optimal degree of oxygenation of the mass undergoing the composting process. The factors that determine the porosity are the size and shape of the materials and the degree of humidity of the mass. Larger and more uniform particles increase porosity, whereas smaller particles have a higher aerobic decomposition rate from the effect of microorganisms. A balance is therefore needed between microbial activity and compactation of the mass. In general terms, satisfying results are obtained by using ground material with particles with an average diameter between 0,5 and 5cm.

Fig. 6 A young Turkana man gathers the dry leaves of a palm. (Photo: P. Altemura).

Humidity

Water is the medium in which the chemical reactions take place, as well as the diffusion and transport of the nutrients and the movement of the microorganisms. Materials used for composting should have in the order of 55% to 65% humidity levels. The process, especially in the first phase, generates heat through a high degree of evaporation: it is therefore necessary that the initial content of water be higher and that the lost humidity is recovered by humidifying the product. In the case of composting of highly humid substrata (>80%) it is necessary on the contrary to mix the mass with materials rich in fibre and dry substance.

Temperature

Temperature is the most direct indicator of the microbial activity and provides important information regarding the composting process. Composting releases a large quantity of energy in the form of heat which raises the temperature of the mass. High temperatures are necessary for destroying any unwanted microorganisms present in the initial substratum; it is necessary to bear in mind, however, that temperatures greater than 65°C cause the death of most of the microorganisms necessary for the process of decomposition of the substratum It is therefore necessary to control the process in order to avoid excessive heat.

pH

The composting process is not affected to a large degree by the initial pH values of the mass, given the great variety of microorganisms that participate in the process; during the transformation of the organic substratum, the pH can vary, and the optimal values, in any case, are situated between 6,0 and 8,0. In general, bacteria prefer a neutral pH and fungi an acid environment. PH is an important parameter in substrata characterised by a high content of nitrogen, such as manure, since a basic (pH >9) environment fosters the transformation of nitrogen compounds into ammonia and its dispersion into the atmosphere.

Compost conditions

> 65% anaerobiosis

OXYGEN%

>15%

> 5%

< 5% formation of malodorous composts (H_2S, mercaptans, etc.)

Diametre of particles

0,5 – 5cm.

variable

pH

6,5 – 8,5

5,5 – 9

>9 loss of NH_3

T (°C) process

36 – 60 °C

25 – 65°C

Some pre-treatment operations are necessary for preparing the right mixture for initiating the compost process. In the case of matrices selected at the source, after a compliance check and the elimination of any extraneous elements, for which a sifting process may be used, the preliminary treatments are the following:

- the grinding of ligneocellulosic waste, such as pruning, brushwood, etc.
- the mixing of waste with high levels of humidity, such as domestic organic waste, vegetable waste, with dry waste, such as the ground ligneocellulosic waste.

Fig. 7 The area of the Compost Bins. (Photo: L. Vallerini).

Fig. 8 Tutoring activities regarding composting at the M&C Centre. (Photo: J. Nakhulo).

At the conclusion of the production process the compost obtained is characterised by a content of dry matter equal to 60-70% of the total, stabilized and odourless.

Producing compost in arid and semi-arid zones: the oasis of Loiyangalani

Producing compost in the environmental conditions present in Loiyangalani, in relation to the optimal conditions described in the previous paragraph, can be challenging. Many of the factors that have an incidence on the process of production of compost are adverse: high temperature, intense sunshine and high degree of ventilation make it difficult to maintain the necessary degree of humidity, which result in an unfavourable C/N-humidity ratio.

In fact, one of the problems that need to be solved in an arid area such as Loiyangalani is finding the ideal material with which to initiate the composting process. In all the villages surrounding the oasis it is difficult to find organic waste, or any useful material for producing compost.

As can be seen from the photo of a small dump (Fig.2), there is no organic waste (a problem of a different order is the inorganic waste that is accumulating in many inhabited areas). This derives from the fact that almost all organic waste material that could be used for producing compost is actually recycled or thrown away in the areas surrounding the villages. Yet, if a good part of the organic matter derived from domestic waste and animal excrements were gathered at a specific location, it is reasonable to estimate a few hundred kilograms of these materials per day. In fact the population of the Turkana, Rendile and Samburu villages amounts today to approximately 5,000 people, and a good part of their activities revolve around shepherding and rearing of sheep and dromedaries.

Content in carbon, nitrogen and C/N ratio in some compostable matrices

Compostable waste	Organic carbon% s.s.	N% s.s.	C/N
Vegetable waste	30,3	0,9	32,5
Organic waste from domestic activities	37,7	3,1	12,0
Solid fraction of sheep waste	31,8	1,4	22,1
Solid fraction of bovine waste	40,9	1,6	26,1

As can be seen in Table 2, sheep waste presents an interesting C/N ratio, whereas the organic waste derived from domestic activities contains a higher percentage of nitrogen, which gives a C/N ratio that is too low. In order to increase the ratio it is possible to add ligneous or vegetable waste to the composting material, which in Loiyangalani can be obtained from dry palm leaves. This material, which should be previously ground to sizes between 0,5-5mm, however, are already used by the local population for other purposes: the wood for cooking and the leaves for constructing the roofs of huts or of other covered surfaces (Makuti system).

In order to obtain material for composting an information and training plan was carried out with the local population in order to involve everyone in the project. This included the Tutoring and Training of some members of the communities so that they in turn could teach the composting techniques to other members of the communities.

Climate conditions in an arid area such as Loiyangalani naturally

make it very difficult to maintain an optimal humidity level for the production of compost. Levels between 55% and 65% humidity can be difficult to maintain if a series of measures are not adopted. In fact, as previously mentioned, intense ventilation and sunshine, together with high temperatures, which in the dry season can reach 50°C, tend to dry out the mass while in the process of composting. For this reason it is necessary to use special containers which can be closed so as to allow the introduction of materials and water while also protecting the biomass from the actions of the wind and sun.

It was therefore necessary to build an area protected from the wind and the sun and the materials indicated above should be accumulated and mixed in an enclosed are covered with jute fabric soaked in water; this fabric must be kept damp at all times. At intervals to be defined, the biomass must be mixed to allow oxygenation. Actually, every time new material is added to the mix, processes belonging to the first phase alternate with processes belonging to the second; however, it can be concluded that allowing the material to ferment naturally on a bed of vegetation, such as palms, without further interventions it would take at least 6-7 months to obtain a good compost.

Inside the area of the project called *Area Project 4 – NANYORI AREA: Monitoring and Communication Centre-Mo-C Centre, New Small Nursery, Compost Plant* an area of approximately 120m^2 for the production of compost was identified and prepared, with eight Compost Single Compartment Wood Bins (see INFORMATION SHEET 1 COMPOST BIN) and a dump for organic materials to be used for composting purposes, located in front of an entrance gate specifically built to provide direct access to the Compost Plant and to separate the cultivation areas of the Nursery from those devoted to the compost plant.

The entire area is protected both from the sun, by a pergola made of woven palm leaves (Makuti technique), and from the strong wind, with an enclosure also made with woven palm leaves (Marara technique). Additionally, the entire centre is equipped with water taps for irrigation purposes.

THE COMPOST SINGLE COMPARTMENT WOOD BIN

Lorenzo Vallerini

Inside the M&C Centre, or Nanyori Area, there are nr. 8 compost single compartment wood bins (1,50x1,50mx 1,20m high) and an organic waste dump in the front of the second entrance gate.
This single compartment bin serves to hold and confine a compost pile. Access for pile turning and removing finished compost is via the loose front boards which are fitted into the slots formed by four of the upright pots. A sliding cross bar at the top prevents the sides from bulging out. An optional removable top to the unit can also be made for the unit with a sheet of heavy black plastic stapled to the backboards and the cross bar.

List of Materials

6 posts 5X5cm – 120cm long
1 post 5x5cm – 160cm long (cross bar)
18 boards 15x150cm – 2,5cm thick
6 boards 15x145cm – 2,5cm thick
96 galvanized wood screws size number (diameter) No. 10, 40mm (1,5 inches)
4 galvanized wood screws size number (diameter) No. 10, 60mm (2,5 inches)
1 net of a coarse mesh approximately 140x140cm

Construction Sequence

1. Posts

Shave down the ends of the six 5X5cm long 120cm posts to a point with a hatchet. At the location where the composter will be sited, pound in the four corner posts vertically to a depth of 20-25cm into the soil. The posts should be spaced apart (outside of post to outside of post) 145cm from front to rear and 145cm from side to side. Pound in the remaining two posts to the same soil depth immediately behind the front posts. Allow a 3cm gap between the posts for the front boards.

2. Sides and Rear

Starting at the bottom with a 1cm gap, attach six 15x150cm boards to the side posts on each side. Use two no.10 40mm screws per post per board. Allow a 1cm vertical gap between the boards for airflow. After the side boards have been attached, screw and attach six 15x150cm boards to the rear of the unit. Again use two no.10 40mm screws per post per board.

3. Front

Fit the 6 boards 15x145 loosely into the slots formed by the four front posts.

4. Cross Bar

Cut two 7,5cm long pieces with a thickness of 2,5cm. Turn the pieces and attach one under each end of the post 5x5cm long 160cm (cross bar) with two no.10 60mm screws. Fit the completed cross bar across the top of the unit at the front.

If it's possible use a power or hand drill to pilot the screw holes first, to prevent the wood from splitting.
At the end, directly on the ground, extend a net of a coarse mesh and on this 15-20cm thick of dead logs, to facilitate the drainage and to prevent the way in of small animals.

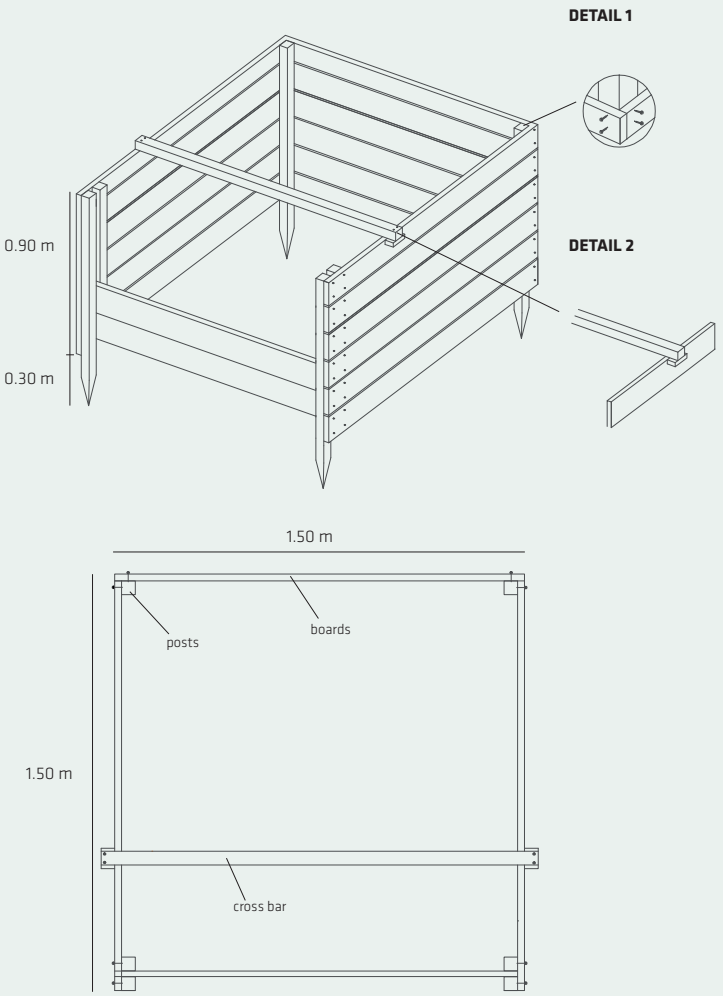


Fig. 1 The detailed design for the project of the Compost Wood Bin. (By: L. Vallerini).

COMPOST FORMATION

Marco Mazzoni

Composting is a biochemical process through which the transformation of various organic materials into a final substance with different physical, chemical and biological characteristics is possible. This process begins with the shredding of the material to be subjected to the composting process. A good shredding, reducing the materials to particles with a maximum length of 4-6cm, is a necessary condition for a good development of the successive stages, especially when working with ligneous material. After shredding, the mass is placed in heaps in the open air where, under the effect of bacteria and fungi, the process of compost formation actually begins. This part can be divided into two different phases:

1. Bio-oxidation phase

During this phase the material undergoes the action of microbes on free organic molecules such as sugars, starches, lipids and proteins. At first, inside the piles there is a fast rise in temperature, up to 60-65°C. At this poin two important phenomena take place at once:

- the elimination of pathogens and of the seeds of wild herbs;
- a general decrease in the number of microbes due to a form of self-sterilisation of the mass as a result of the high temperature.

Without external intervention it is possible to slow down the fermentation process and thus lower the interior temperature of the material. In this first phase the bacterial flora consumes a large part of the organic substance and exhausts the oxygen present in the mass. In order to make the process faster it is necessary to overturn the fermenting mass before the temperature rises to values that could harm the bacterial flora. It is important to maintain a high degree of oxygen to prevent anaerobic processes which would result in bad smells (hydrogen sulfide and mercaptans), and in the production of substances that could be toxic for vegetation.

2. Maturing of the mass

At the end of the bio-oxidation phase a second stage begins, known as 'maturing'.

Also in this stage oxidation processes with bacteria take place, yet the speed of transformation in this case is slow and high temperatures are not reached. In this phase biochemical processes are carried out by microorganisms which bring about the formation of molecules derived from the polymerization of the organic substances that were left-over from the first phase; these organic complexes that were absent in the original material are generally defined as 'humic complexes'.

Fig. 1 The information sheet on the use of the compost made for the activities on Information and Awareness of the project. (By: L. Vallerini).

In the environmental conditions existing in Loiyangalani, the starter organic can be made of animal excrements (from goats, donkeys, dromedaries, etc.) and plants (pruning waste from palms, acacia, etc.): to this may be added in future pruning waste derived from the cultivation of vetiveria and from the Nursery, as well as form the other zones of the Palmeraie and Afforestation.

Temperature, intensity of the wind and of sunlight, as well as drought, can seriously put to the test the bacterial flora: it is therefore necessary to protect the compost heap from these atmospherical factors by covering it with materials such as jute fabric (or the woven fibres from the root of the vetiveria), in order to keep it always humid and away from direct sunlight.

Vegetation

The Palmeraie: enlargment of the oasis and food production for the local population

Irrigation canals in a Date Palm grove. (Photo: L. Vallerini).

Fig. 1 Foggara system for gathering and storing water (Source: Laureano P. 1995, *La piramide rovesciata Il modello dell'oasi per il pianeta Terra*, Bollati Boringhieri Ed., Torino)

Lorenzo Vallerini

As stated in many UNCCD documents, as well as of other international and Kenyan organizations[1], the fight against desertification must act both against the phenomena that increase the decay in the productive capacity of the soil, ensuring sustainable uses for the soils that are not yet depleted, and promoting the participation of the local communities.

And what better system for involving the local populations if not that of combining in a reciprocal relationship activities which expand the vegetation systems and those which produce foodstuff, implementing agricultural activities, however simple, yet efficient,with the ultimate aim of reducing poverty?

In Kenya the experience of the *Green Belt Movement*, founded by Wangari Maathai in 1977, based its 'planting' activities not only on the expansion of vegetation in various areas of Kenya – over 51 million planted since 1978 –, but also and especially on the involvement of local communities, of women in particular, encouraging community work, the cultivation of the plants to be used in the new plantations, the safeguarding of the soil and of the water resources and the production of food and other products which can guarantee some economic income[2].

Also the initiative by the *Slow Food Association, '10.000 gardens in Africa'*, to be carried out by schools in African villages, and which in Kenya established 368 in the south of the country, is not only aimed to provide fresh and healthy food, but also to create a network of people who are aware of the value of their land and of their culture, based on ten principles:

- The gardens are developed by a community.
- They are based on the observation-knowledge of the land, of the existing plants and of the available resources.
- They do not need large spaces.
- They are spaces for biodiversity because no chemical fertilizers or pesticides are used, but compost and natural products, nutritious and resistant varieties are planted (vegetables, medicinal and aromatic herbs, and fruit trees such as bananas, mangos and citrus).
- They produce their own seeds.
- They are cultivated with sustainable methods.
- They preserve water.
- They serve as open-air classrooms where both children and adults can get to know the autochthonous plant varieties and farming is valorized and taught.
- They serve as a simple and economic tool for obtaining healthy and nutritious food and serve as well as places for social interaction.
- They function as a network, which means that the gardens can exchange seeds, ideas and information[3].

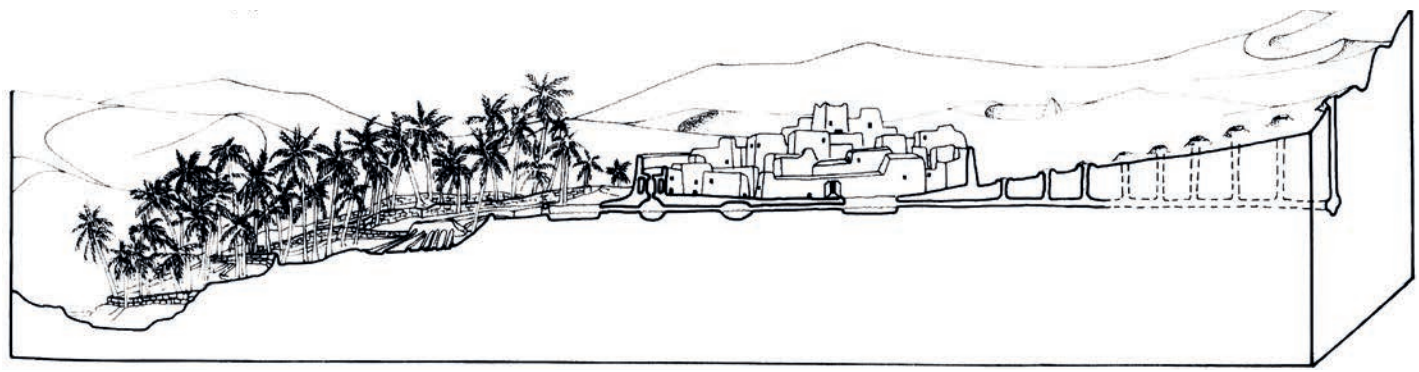
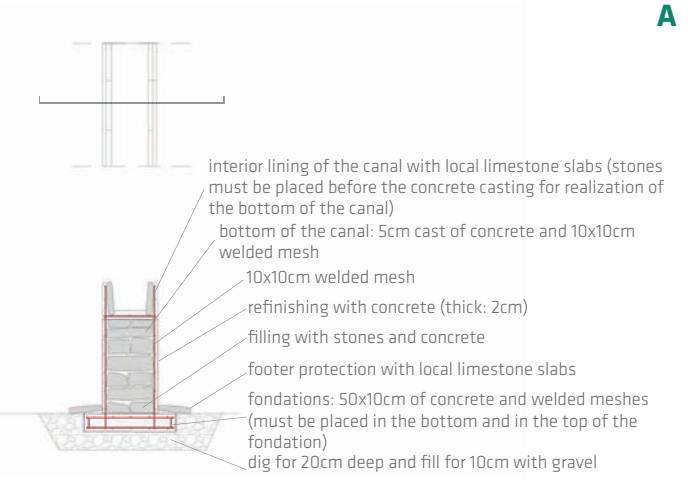


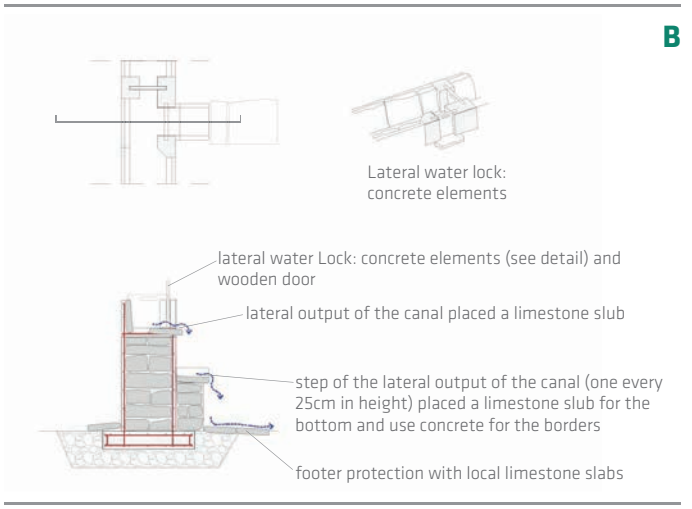
Fig. 2 Detail A: main canal | 1/20. (By: L. Vallerini).

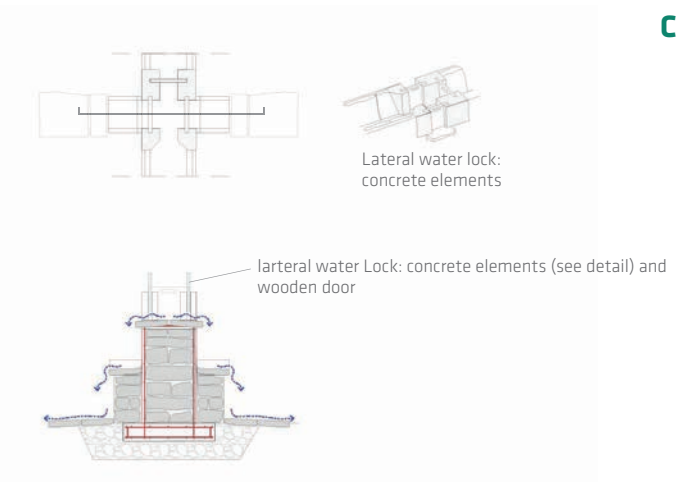
Fig. 3 Detail B: connection between 1 lateral canal | 1/20. (By: L. Vallerini).

Fig. 4 Detail C: connection between 1 lateral canal | 1/20. (By: L. Vallerini).

The 'land' is, in other words, the foundation for the future, for cultural identity and development in harmony with the environment.
It is based on these principles and ideas that the project for the 'Palmeraie' was born.
As mentioned earlier, the area where the Palmeraie was established is next to the eastern section of the oasis and covers a surface of approximately 5.500m^2 in which planting techniques for the *Phoenix dactylifera*, or Date Palm were tested in the proximity of a Doum Palm grove, which is present throughout the entire oasis. This was done both for recovering a strip of land that was suffering from erosion and loss of vegetation, and to initiate the cultivation of dates, fruit and vegetables.
The cultivation of the Date Palm is one of the oldest in the world and appears simultaneously in Egypt and Mesopotamia approximately 6.000 years ago. From ancient Babylonian and Egyptian texts it is known that the vast cultivated Date Palm areas were developed using artificial pollination, with remarkable economic success, to the point that the Date Palm had been chosen as symbol of fertility and dates were offered to the gods. It was however the Phoenicians (which gave the plant its name 'Phoenix') approximately 3000 years ago that spread the cultivation of this plant throughout the southern Mediterranean and in arid and semi-arid zones, which resulted in the development of sophisticated hydraulic techniques (such as the 'foggaras' or 'khettara') aimed at holding and accumulating the large amounts of water necessary for the cultivation of the date palm[4].
The expansion of the cultivation took place between the 7th and 14th centuries thanks to the merchants and pilgrims that travelled to and from Mecca, gradually conquering the desert and resulting in an increasing physical and economic development of oases and of the cities linked to them.
Oases soon became prosperous agricultural centres where not only dates were produced, but also cereals, fruit and vegetables, since the cultivation of the Date Palm associates with these other cultivations in a virtuous circle of land taken from the desert, enhancement of the fertility of the soil, conservation of water resources and increase in agricultural production, with a consequent rise in the economic, cultural and religious power of the oases and their cities.
With this historical background of environmental and productive successes it seemed a good idea to initiate the cultivation of the







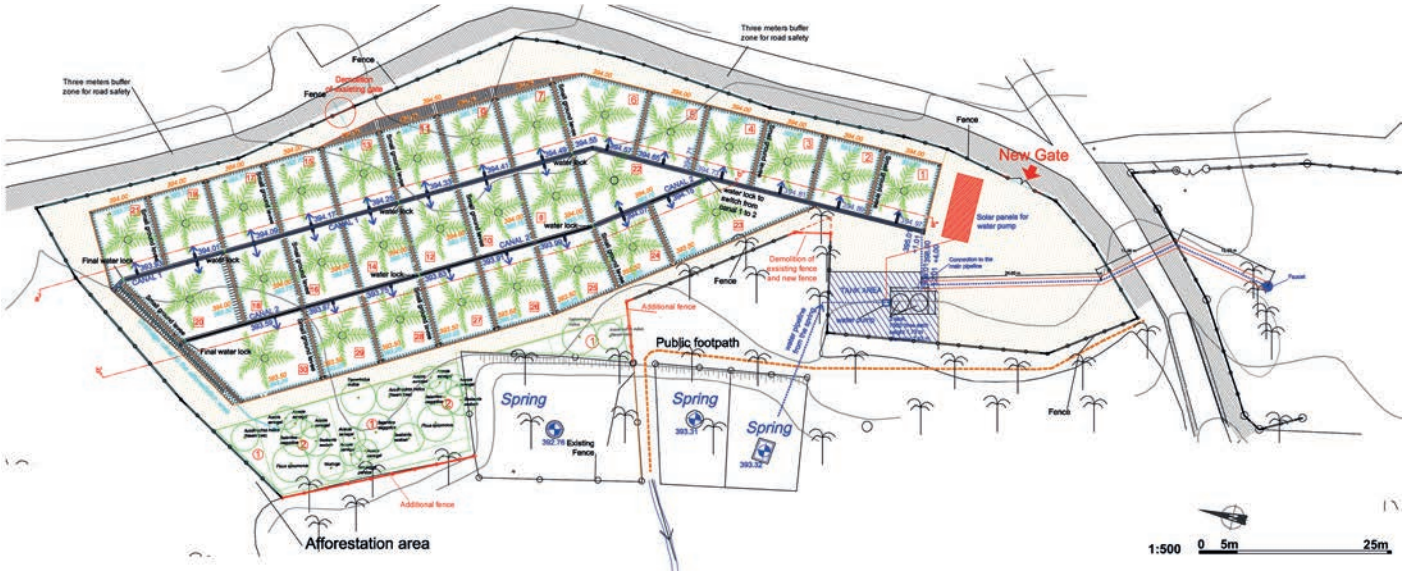


Fig. 5 The project for the Palmeraie area. (By: L. Vallerini).

Date Palm in Loiyangalani, with the purpose of achieving some of the objectives that this project had established: to expand the oasis, to save an ecosystem which is thinning out even today, and to provide an opportunity for bettering the diet of the local populations.

In fact, in the area chosen the soil was not in such a bad shape, and after having analysed it resulted deep enough and with the proper soil nutrients for the cultivation of the Date Palm. In addition, the proximity to the springs ensured the necessary amounts of water for irrigating the palms and producing large quantities of dates.

The only drawback is the fact that the local communities of El Molo, who are fishermen, and of the Samburu, Turkana and Rendille, nomadic shepherd tribes which have now become settled in Loiyangalani due to the lack of good grazing and fertile lands, are not culturally inclined to agricultural activities; the project depends to a certain extent of making farmers out of them, at least partially, with the ultimate objective of guaranteeing a sustainable future for them in their own lands, and not only a difficult fight for survival.

The Information-Awareness and Tutoring-Training activities, which began at the same time as the 'physical' and material works aimed at providing infrastructures to the area, involved groups of people, yet longer times and a constant assistance will be needed in order to integrate this new 'settled' culture to the existing nomad-shepherd communities.

Yet a good part of the Berbers in Maghreb did just this, without losing their nomadic culture.

The elements of the area are the following:

1. the system for piping water from the springs;
2. the system of water distribution canals;
3. the 30 cultivation areas, one for each Date Palm;
4. the protection of cultivations from livestock and strong winds.

The Date Palm, although a desert plant whose roots are capable of using water from the underground, needs constant irrigation in order to produce fruits in abundance.

Palm growers have developed complex irrigation systems throughout the centuries in order to guarantee an equitable distribution of water to the various cultivators inside the oasis, as well as sufficient water irrigation.

Irrigation canals were designed and built following experiences in north African oases and palm groves. In Touzer, a city in the Tunisian desert, the 'Palmeraie' covers 1000 hectares with 400,000 palms, and the system of water distribution from 200 artesian wells is still the one that was designed in the 13th century by the hydraulic engineer Ibn Chabbat, who is now considered a national hero. And this system, in addition to sluices and locks that guarantee adequate distribution to the various lots, in accordance with pre-established and rigidly respected turns, uses a network of brick and stone canals that distribute the water to the various sections.

The irrigation system constructed for our Palmeraie uses overflow water from the nearby springs drawn with a solar-powered pump into three 5,000lt tanks placed on a metal structure at a height appropriate for then distributing through gravity the water into the canals and from them to the individual plants.

Fig. 6 Palm groves in north Africa, Touzer (Tunisia). (Photo: L. Vallerini).

The canals, built with local stone and hydraulic cement, form a 'Y' on whose sides 30 squares measuring 100m^2 each (10mx10m) with a palm in the centre are located; the water is distributed into the individual squares through a sluice that permits the water to pass, and which is closed if the water is intended for the following square. This system permits daily irrigation of a certain number of lots, and then another group of lots on the following day, and so on and so forth in a cyclic and constant flow of water, the amount of which depends on the availability from the springs.

As mentioned earlier, the Date Palm tends to better through time the quality of the soil and its fertility, being careful, however, not to increase the presence of salts through the irrigation system. This permits planting other species in the same 100m^2 plot, such as fruit trees and vegetables. Constant irrigation obviously favours a homogenous growth and a constant production.

Every single lot was worked with a spade and the soil mixed with compost produced at the Nursery of the Nanyori Group, after which a *Phoenix dactylifera L.* or a *Phoenix reclinata* was planted at the centre of the lot.

In order to obtain dates it is necessary that the female plant be pollinated by the male (one 'male' plant for every 10-14 'female' plants), either 'naturally', with the help of the wind, or even better, manually, as is usually the case in Date palm groves in order to guarantee a good harvest.

After the first stages of growth of the palms, four fruit trees were planted on the four corners of the lot, Pomegranate, Apricot Tree, Orange Tree, Lemon Tree, etc. which constitute the mid-vegetation level, whereas on the ground level vegetables were planted.

Species - Plant Distribution in Palmeraie Area	N°
Phoenix dactylifera L. (2 males and 28 females) *and Phoenix reclinata* (1 male and 9 females) (Date Palm)	30+10
Punica granatum (Pomegranate)	30
Prunus armeniaca (Apricot Tree)	30
Citrus xsinensis (Orange Tree)	30
Citrus xlimon (Lemon Tree)	30

It was not easy to obtain the Date Palms in order to begin cultivation because they are not much used in Kenya, where there is not tradition of growing these plants, both because importation from other countries is almost entirely forbidden to avoid the diffusion of pathologies and of parasites that are very dangerous for all species of palms.

It was also difficult to find fruit trees that can resist the tough climate conditions of Loiyangalani. The ones chosen are not common in this area and it was also difficult to obtain them.

Research began at the Malindi Tropical Tree Nursery which is located on the coast near the city of Malindi and in other nurseries-production centres such as the Mandhari Plants and Designs, the KEFRI Nurseries, the KALRO Nurseries, the Suba Environmental Education Kenya and later at the Natural Green Farmtech Nurseries in Nairobi.

Fig. 7 Planting Date Palms at the Palmeraie Area. (Photo: J. Nakhulo).

Fig. 8 Canals and Palmeraie under construction. (Photo: M. Folini).

NURSERY	LOCATION	AVAILABLE PALM VARIETIES	ORIGIN AND STATE OF GROWTH	FRUIT TREES
Malindi Tropical Tree Nursery	Malindi Kenya	*Phoenix reclinata, Phoenix canariensis, Phoenix roebelenii*	These varieties originated from Senegal and mainly propagated through seeds. Growth stage between 90cm to 2.5m	No fruit plantlets (deals mainly with flowers)
Mandhari Plant and Designs	Malindi and Nairobi Kenya (A subsidiary of Malindi Tropical tree nursery)	*Phoenix canariensis, Phoenix roebelenii*	Palms originated from Senegal. Propagated from seeds. between 1m-3m of growth	Mainly engaged in landscaping and home décor plantlets
Kefri Nurseries	Gede in Arabuko Sokoke Forest	*Phoenix canariensis Ravenalla madagascariensis Phoenix rupicola Cocos nucifera Phoenix reclinata*	Propagated from both seeds, tissues and offshoots	Fruits plantlets available
S.E.E.K Nurseries	Suba in Homa Bay County (Reffered to by Kefri Mombasa. Reached by phone)	*Phoenix canariensis, Phoenix roebelenii*	Propagated mainly from seeds	Fruits seedlings availables
KALRO	Nairobi	None	N/A	Fruit seedlings available
Natural Green Farmtech Nurseries	Nairobi (Reffered by S.E.E.K)	*Phoenix reclinata Phoenix dactylifera*	It had limited number of *Phoenix dactylifera*. propagated mainly from seeds, between 75cm to 1.5m height.	Fruit seedlings available except Apricot

The last, but not least, of the elements of the project is a fence built first with barbed wire for setting the boundaries of the area, and then completed with the 'Marara' system, which is widely used throughout the oasis and which uses dead logs, palm leaves and other vegetation woven together. This system is used throughout the oasis for establishing physical barriers between cultivated lands and the desert winds. Its main purpose is precisely as a windbreak, but also as a protection from the hundreds of goats that graze in the area and which in periods of drought attempt to eat even the rough palm leaves.

This experimental development should be a first step in further expansions of Date Palm cultivation in the eastern section of the oasis, so as to safeguard the springs and the most important part of the ecosystem of the oasis.

Endnotes

[1] Secretariat of the United Nations Convention to Combat Desertification 2006, *Implementing The United Nations Convention To Combat Desertification in Africa-Ten African Experiences*, Bonn, Germany.

[2] Available online at http://www.greenbeltmovement.org/who-we-are.

[3] Available online at https://www.fondazioneslowfood.com/it/cosa-facciamo/10000-orti-in-africa/il-progetto/.

[4] *Foggara* are a kind of filtering tunnels which draw water from an underground phreatic level toward the lots determined for cultivation purposes. *Khettara,* instead, consists in a series of subterranean canals which follow a slight inclination at a depth of 5 to 10 meters below the surfact of the ground, the purpose of which is to collect the water derived from the scarce rainfall which would otherwise percolate into the depths due to the dryness of the ground. Water, in fact, is collected and preserved only where there is vegetation; it seems a paradox, but the plants do not consume water, but rather retain it, in other words they enhance the hydric retention capacity of the soil and its fertility. In this way they ensure their survival! Obviously this ocurrs only when the adequate ecologic conditions of a balanced ecosystem exist.

PHOENIX DACTYLIFERA

Lorenzo Vallerini

Fig. 1 Date Palm Structure. (Source: http://bit.ly/2G5KGw4).

Fig. 2 The dates. (Photo: L. Vallerini).

Fig. 3 The off shot from the base of the trunk. (Photo: L. Vallerini).

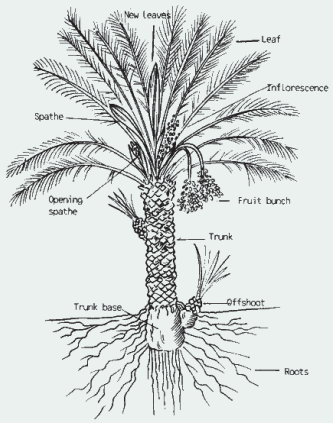
The Latin name *Phoenix dactylifera* means 'the tree of the Phoenicians with fruits which resemble human fingers' (*daktilos* = finger).
The Date Palm is not actually a tree but rather a highly developed herbaceous specie which belongs to the class of the Monocotyledons and to the genus of the Palmaceae or Arecaceae.
It can reach a height of of between 20 to 30 metres and has a tronk visibly covered in the remains of the sheaths of the fallen leaves. At the top of the trunk there is a maximum of 20 to 30 pinnate leaves, 5-8 metres long, linear, rough and yellow-green. Every year approximately 10 new leaves are formed, whereas at the base of the tuft the older ones turn yellow and dry out.
It does not have a main root apparatus but a 'bulb' from which strong fibrous roots spread out. There are four types; superficial, short and horizontal for breathing, deeper ones for absorbing nutrients from the soil and those for absorbing water, some of which extend until the reach water underground.
Reproduction takes place through shoots or through seeding in Spring. However, it usually takes place through shoots which take root at the base of the palm; these plantlets can be transplanted immediately or after a year at the Nursery.
It is a long-living plant which can live over a century long and produce more than 100kg of dates per year.
A native of Asia Minor, it grows in hot and desert regions of the planet, especially in the Middle East, India, North Africa, the Canary Islands and the south of the United States.

Pollination: It is a dioecious species, which means that there are male and female trees, and pollination requires the same number of male and female plants. Using artificial pollination, however, the ratio can be 1 to 50. Therefore the choice of the plants for deriving the pollen is very important since this species is characterised by the phenomenon of *metaxenia* [1], in which the pollen has an influence on the form, size and ripening process of the fruits. From some male plants large quantities of good quality fruit can be obtained.
There are male and female flowers on both male and female plants. While male flowers are white, small and gathered in inflorescences near the stem of the leaves which are up to 1 metre long; female inflorescences, which have the same size and colour but are less numerous, tend to bend downward with the development of the date-fruits.

Climate, soil and water: It prefers sub-tropical and temperate warm climates, yet the plant can survive in temperatures as low as -5°C, however, for fully ripe fruit temperatures as high as 30-40°C are necessary, together with a low relative degree of humidity. In warm and humid climates the palm shows an excellent development, providing however less quality and quantity of fruit. The optimal situation is under direct sunlight. Regarding the soil it is adaptable, preferring however fertile and well-drained soils.
This species needs large amounts of water, which means it grows well only in the oasis, near watercourses and in areas in which irrigation is available.

Variety: There are many cultivars of Date Palms, divided into three groups: with soft, semi-soft and dry fruit. The soft-fruit variety are considered the best dates because they are larger, tastier and softer. The type that produce semi-soft fruit are productive, although inferior in quality to the previous category. The dry fruit cultivar are the ones that produce the greatest quantities, but of lesser quality fruit.
The most common dates available are the ones belonging to the second group. The most widespread cultivars are: Majhool, Deglet noor, Ameri, Deri, Halawi and Zahidi.
Some varieties (Berhi and Hiann) are marketed fresh.
Dry dates are more dark and wrinkly, with oblong and irregular shapes. The fresh varieties are smooth and perfectly cylindrical.

Nutritional properties and other products: Dates are a good source of nourishment. They are considered an excellent source of energy as well as a healthy and nutritious food: fresh dates are certainly the healthiest, having less calories and more vitamins than the dry varieties. 100 grams of dry dates contain 282 calories, whereas in the case of fresh dates this number descends to 142 calories.
Dates contain vitamins of the B group (vitamin B6 is beneficial for the health of the brain and increases mental performance), vitamin A and C, mineral salts, iron (the large content of iron prevents anemia), and natural sugars such as fructose. Among the mineral salts present there is potassium, magnesium, sodium, phosphorus, selenium and calcium (selenium, manganese, copper and magnesium help to prevent osteoporosis). Among the amino acids present in dates are valine, serine, lysine, alanine, glutamic and aspartic acid.



Muslims use dates to break the daily fast during Ramadan, not only because that is what Muhammad did, but also because it is a good way to quickly absorb many nutrients.

Considered a powerful aphrodisiac in India, dates have many other beneficial qualities.

The vegetable fibers present in the date enhance digestion, as well as blood circulation and consequently are good for the health of the heart.

Dates alleviate inflammations, especially those which affect the respiratory system during a cold. They provide energy for the body, increasing the available reserves thanks to the large content of natural sugars. Their high content in iron make them ideal for people suffering from anemia. They are also used in remedies against constipation, whereas the high content in potassium and in vegetable fibers make it useful also against diarrhea. The large content in potassium makes dates beneficial for the nervous system in general, and is especially good as part of the diet of the elderly, whose nervous system tends to weaken with age.

Dates have cosmetic properties as well, such as in fighting acne.

There are many uses for dates: from jams and drinks such as juice or wine, to biscuits and sweets.

The fibers of young leaves are used to make carpets, brooms and rough fabrics.

Date Palms in Kenya: Date Palms were introduced in Kenya in the early 20th century, when it was imported from Iraq and Bahrein, and later, in the Fifties, from the United States and Pakistan. Planted in various regions of Kenya (Malindi, Matuga, Galole, Tareta, Isiolo, Garissa, Moyale), the largest plantations are located in the area of Turkwell in the Turkana District, to the north-west of lake Turkana[2]. These plantations were located in these arid or semi-arid zones both for contributing to food production and fighting poverty in the region and for satisfying part of the demand of dates for consumption throughout the country. In fact Kenyan Muslims (15% of the total population), every year during Ramadan import and consume between 500 and 800 tonnes of dates.

Between 1970 and 1980 a few thousand shoots of fifteen different varieties were planted in the alluvial plain of river Turkwell with support form a project funded by FAO - Food and Agriculture Organization and by the Government of Kenya. Between 1985 and 1990 production reached 1,250kg, which represented approximately 80kg per plant[3] per annum with good profits for farmers, but especially positive for the diets of the local populations. From 2002 production slumped due to the abandonment the groves, the absence of or incorrect pollination, as well as scarce irrigation, pruning and fertilizing[4]. This, as well as other initiatives for growing Date Palms in Kenya failed for a series of reasons.

Often the varieties used were not the most appropriate for the areas in question, additionally, in many cases the 'common' property of the land did not provide incentives for private enterprise, and finally the lack of involvement of the local communities and the absence of training and information on cultivation techniques resulted in the failure of the initiatives, despite the fact that there is a wide potential market for dates in Kenya and that this fruit can contribute greatly to providing a richer and more balanced diet to the ex-nomadic people that live in the area and who have been forced to become sedentary as a consequence of the reduction of grazing lands and desertification.

Endnotes

[1] Metaxenia is the influence of the male cell on the ovary and the adjacent parts during the pollination between two plants, male and female: modification can be observed in the fruits in terms of size, chemical composition, etc.

[2] The areas recommended for planting and growing Date Palms in Kenya are: the North East (Marsabit, Garissa, Wajir,Isiolo, Mandera), the Rift Valley (Turkana, Baringo, Elgeyo Marakwet), the Coast (Tana River, Kilifi, Kwale, Taita Taveta Districts) and the Eastern provinces (Makueni, Kitui).

[3] Recorded in the Turkwell Irrigation Scheme plantation managed by the Nowegian Agriculture Development Agency (NORAD).

[4] "In 1984 NORAD sunk 14 boreholes to provide water for irrigation. Water was subsequently channelled from the Turkwell River to a storage tank for irrigation. This system worked until 1994 when the channels silted up and were no longer operational. Technical and organizational control of irrigation is necessary so that irrigation can be sustainable. In the early 1990s the date palms were irrigated only once or twice a year. If the date palms had been sufficiently irrigated, they would yield regularly and provide dependable income" (Wasilwa et al., 2007).

The Cultivation of the Date Palm

Palm grove in North Africa. (Photo: L. Vallerini).

Fig. 1 Typical soil profile in the date palm garden area. (Photo: P. Magazzini).

Fig. 2 Parcels preparation and manuring in Siwa Oasis (Egypt). (Photo: P. Magazzini).

Piero Magazzini

Date Palm in Loiyangalani

In the Oasis of Loiyangalani the date palm plantation was caried using two different species: *Phoenix dactylifera* and *Phoenix reclinata*. Date palms grow on different types of soils but the best yields can be obtained with sandy loams. Soils should be permeable with a good drainage and a deep ground because roots grow deep (6 meters) into the soil for water uptake. The date palm is considered to have the highest salt tolerance compared to all other fruit crops. Also alkaline soil conditions with a PH up to 8 are tolerable.

Soils in the palm date area are on a flat surface (Mapping unit 7), on lacustrine sediments, with light colluvial basaltic coarse materials coming from the upper basaltic hills erosion. Trees vegetation is absent up to the brink of the escarpment, where groups of doum palm occur, while grass vegetation is composed of grassy pillows scattered on sandy sediments probably of aeolian origin.

The soils have a moderate profile evolution (An-Ab-Bk_BC-C), with A topsoil horizons on rough colluvial materials and more sandy textures, while the deeper horizons have finer textures, even clayey loam, with low salinity but high alkalinity. The fertility elements are usually rather defective, and should be integrated with local mineral or organic fertilization. The good capacity of water retention and the low salinity makes the area suitable for irrigated tree crops, being however careful of removing the soluble salt that may be present in the topsoil. The soils belong to the *Calcaric Cambisols* (Sodic, Alcalic) (FAO-WRB, 2006).

Propagation

The most frequent technique for the propagation of the date palm is by using offshoots. Reproduction by seed is not much used because it can create trees with fruits with very different characteristics. Regarding the reproduction by offshoots, it is commonly obtained by removing the present offshoot from the mother plant. We proceed

by dwelling the offshoot directly into the ground or after a year at the nursery. To eat the first fruits we must the wait six or seven years after planting, only some early varieties start producing already at by the fifth year. Propagation of date palms can be done by using seeds (sexually) and by using offshoots (asexually). When using seeds 50% will develop as male date palms which do not bear fruits. For that reason the use of offshoots (vegetative propagation) is the most common one. Offshoots are cut with a chisel and/or machete from proven female cultivars and transplanted into a nursery with good growing conditions (wind protection, shade trees, soil etc.) in order to support the development of the roots.

After one year (or earlier) young date palms are transplanted to their permanent place. The right time of transplantation depends on the development of the root system as well as on the number of palm leaves (10 to 12 are recommended).

Sometimes offshoots already have developed roots at the mother plant. In these cases offshoots can be planted directly.

Soil preparation and Planting

Before planting a new date plantation land has to be prepared by building a drainage and irrigation system. No artificial drainage has been carried out in Loiyangalani due the good permeability of the soils.

When establishing a new date plantation, certain actions need to be implemented to ensure the long term success of the plantation. One of these actions involves the initial land preparation which should be done prior to transplanting the plant material.

The mechanical or initial soil preparation concerns mainly the preparation of a field for further detailed preparation such as irrigation system installation, hole preparation, etc. Actions, if applicable to the area, include:

- debushing/bush clearing;
- removal of stones and rocks;
- ripping;
- levelling of the soil.

In general, most soils are poor in organic matter content and the improvement of this situation plays an important role in soil fertility. Some of the advantages of a higher humus content in the soil are summarized as follows:

Fig. 3 New Palm tree plantation with secondary plants. (Photo: P. Magazzini).

Fig. 4 Young palm tree cultivation 10 years old in Siwa Oasis (Egypt). (Photo: P. Magazzini).

Fig. 5 New palm tree plantation with drop irrigation in Siwa Oasis (Egypt). (Photo: P. Magazzini).

- enhances crumb formation which improves the respiration of the roots;
- increases the water infiltration rate;
- increases the water holding capacity;
- lowers soil compaction and crust formation;
- limits the harmful effects of alkalinity and improves the leaching of salt.

In traditional date orchards, especially in the oasis, the density of palms is very high with the intention to form an almost closed canopy. The high density provides shade and protection from wind, thus creating a micro-climate in which the harsh conditions of a hot and dry climate are tempered to make living conditions somewhat more sustainable.

In Loiyangalani the specialized plantation was carried out using a planting system with a grid of 10mx10m providing space for the use of machines as well as for secondary crops.

Every grid 10x10m large will be delimited by 20cm high small levees and will have an opening in the irrigation canal to allow the distribution of the necessary water to the complete flooding of the grid.

The young date palms are planted in a hole (90cm deep x 90cm wide) in order to put the roots closer to the water table. In traditional cultivation systems the surface earth is removed and replaced by a mixture of organic manure, sand and ash. In organic cultivation systems it is recommended to also add composted organic material.

It is recommended to prepare the holes two to three month before planting. After planting the young date palms are watered daily for at least one or two weeks. With the objective to protect the date palm and to improve the growth conditions young plants should be surrounded by fences (e.g. with cut date palm leaves or Marara).

In addition a coat out of straw and palm leaves is put around the shoot to reduce water losses.

Date palms can be planted throughout the year provided a sufficient water availability is given. In order to provide natural pollination two to three male shoots are planted with approximately 100 female shoots to gain pollens.

Growing Date Palms

Date palms with their dense leaves give a good cover to the ground from hot sun, where other plants can grow. Traditionally, intercropping with other fruit trees (citrus, pomegranates, olives, grapes, guava) or arable crops (alfalfa, barley, beans, etc.) is carried out in many of the main production areas. Without the shade provided by the date palms other crops very often cannot grow.

The following average amounts of nutrients are citied in the literature looking on conventional date palm plantations: 500g N (nitrogen), 300g P (phosphorous) and 250g P (potassium).

Average nutrient up-take of date palms (g/plant)		
N (g)	P (g)	K (g)
500	300	250

In organic cultivation fertilization strategies are based on green manure and compost.

This strategy doesn't differ much from the traditional way of fertilizing date palms. Animal manure was applied by digging a trench around the tree in order to bury the animal manure. Nitrogen was provided by intercropping of alfalfa (and other appropriate leguminous plants). Organic cultivation systems require a sufficient supply of composted organic materials (animal manure with other organic materials like straw and other organic waste material) on a regular basis.

At least every four years compost should be added to the date palm. For that reason the compost must be brought into the soil around the stem. Regular application of organic materials improves the water holding capacity and therefore the efficiency of irrigation.

Irrigation

An Arabian proverb says that the "date palm must have the head in the fire and foot in the water".

In north Africa irrigation water is traditionally supplied by a surface system, with main and secondary channels.

The irrigation is the condition for the date palm tree cultivation achievements. Date palm needs about 15.000m^3/ha/year of irrigation water, particularly during the flowering and fruit growing seasons, as shown below in the palm tree vegetative calendar. This means that in our palm tree cultivation (3.100m^2) we need about 4.650m^3/year of irrigation water.

The source supplies water with an amount of about 20l/sec, which means that the total water amount will be approximately 28.8m3/

Fig. 6 Irrigation Schedule 1 (red polygon).(By: P. Magazzini).
Fig. 7 Irrigation schedule 2 (red polygon). (By: P. Magazzini).

Fig. 8 Date palm male flowers. (Photo: P. Magazzini).
Fig. 9 Date palm female flowers. (Photo: P. Magazzini).
Fig. 10 Manual Pollination procedures. (Photo: P. Magazzini).

day. The three tanks in the palm date cultivation will store about 15m3/day, leaving free to the population about 13.8m3/day.
The scheduled irrigation will be divided into two days, watering 15 plots per day at the same time as shown in the following table:

Schedule	Plots	Daily Water amount in m3	Annual water amount in m3
1	1-15	15	2745
2	15-30	15	2745

The total amount of irrigation water per year will be about 5490m^3, with a sligh surplus regarding the total required calculated amount of water. The surplus water will balance the loss by evaporation and by seepage along the irrigation canals.
The water scheduling will be divided the 30 plots as shown in the Schedules 1-2.

Pollination and Pruning

Date palm pollination is fundamental for a good production and should be carried out by insects, or by wind, or artificially by man; with a male/female ratio of about 1 to 50. The selection of the male for artificial pollination is important because the quality and the quantity of the fruits depend on the pollen (size, shape, harvesting period and so on). The optimum climate conditions for palm trees are the humid subtropical and the warm temperate climates. The only constraint is the harvesting requirements to obtain sweet and high quality fruit. For that the date palm needs a low humidity and temperature from 30 to 40°C during the last three months before harvesting.

Humans have provided pollination since ancient times by using male flowers (on the right) on female flowers (on the left).
The pollination procedure has been carried out by man using a long ladder or climbing directly on the palm and distributing the pollen of a male palm to about twenty female palms. Approximately six months are needed from fecondation to the ripening.
Pruning operations are easy and consist only cutting off the old leaves, cleaning the bunch and maintaining a good leaf cover for underground cultivations.

Diseases

Most occurring fungal diseases:

- Omphalia root rot: Triggered by *Omphalia pigmentata* or *O. tralucida*. This fungus doesn't exist in the stem, only in the roots.
- Inflorescence rot (and/or Bayoud): Triggered by *Fusarium oxysporum f. sp. Albedinis*. This fungus exists in the soil. Symptoms: white chlorite colour and fade of the palm leaves. Bad conditions of cultivation and an intensive cultivation of alfalfa and vegetables in rotation supports an infection. The following varieties have a lower fruit quality but they are supposed to be resistant against inflorescence rot: *Takerboucht, Bou Jigou, Taadmant* and *Bou Stammi*.
- Diplodia disease: Triggered by *Diplodia spp*. Can occur in young cultivations.
- Terminal bud rot: Triggered by *Ceratocystis paradoxa*. Rot of the terminal buds in older palms.



- Khamedj: Triggered by *Mauginiella scaettae*. Rot of the flowers which can lead to a total destruction of the inflorescence.
- Fruit roots: Triggered by *Aspergillus niger, Rhizopus nigricans, Alternaria citri*.

Pests

- Cottony cushion scale: *Parlatoria blanchardii* and *Phoenicoccus marlatti* are widely spread. Sucking on the leaves leads to early death of the leaves. Cottony cushion scales need humidity and wind free areas and therefore exist inside the plantation. Biological control is done with natural predators like bugs of the species *Pharascymnus, Cybocephalus* and *Chilocorus bipustulatus* but also by appropriate methods of cultivation.
- Bryobia: *Oligonychus afrasiaticus* and *Paratetranychus* simplex are wide spread in North Africa and in the Middle East and *O. pratensis* in California. *Bryobias* infest the leaves and unripe fruits. They need dry and windy conditions. The use of *Arundo donax* in mixed cultivation supports their spreading therefore it is recommended to use other crops for mixed cultivation.
- Caterpillars: Most common are the caterpillars of the butterfly Ephestia cautella and Batrachedra amydraula, which eat the leaves and penetrate into the fruits. Bacillus Thuringiensis is used for biological control.
- Bugs: Rhinoceros bug of the species *Oryctes spp*. They eat tissue of the young leaves and destroy the area of vegetation. There are different possibilities of biological control: Removal of their hotbeds like rotten plant material and green manure. Artificial preparation of hotbeds for catching, biological control by the fungus *Metarrhizium anisopliae* and the virus *Rhabdionvirus oryctes*.
- Fruit bugs of the species *Cotinis texana*, *Carpophilus hemipterus, Coccotrypes dactyliperda*. They destroy ripe fruits and inflorescences. Inflorescences are usually wrapped in bags to be protected.

Rodents

As in other palm crops rats, mice and other rodents may cause damages to the trunk as well as to the fruit. For that reason it is recommended to support predators like owls with the aim of controlling the population of rodents in the date plantation. Another mechanical way of reducing fruit damages is to place a mechanical device around the stem in order to make it impossible for rodents to climb up the tree.

Production and harvesting

The colour of the dates indicates the right harvesting time. At the 'Khalal' stage dates are partially-ripe showing a yellow or red colour (depends on the variety). At this stage some dates are already harvested in spite of the fact that the moisture and tannin content is still very high. Most of the dates are harvested at the fully-ripe stage. Furthermore, the sugar content is higher and/or moisture and tannin content is lower.

Harvesting is a labour intensive as dates are hand picked. In intensive date plantations cranes are used to lift up the workers. However, in most of the cases workers have to climb up the date palm in order to reach the fruit brunches.

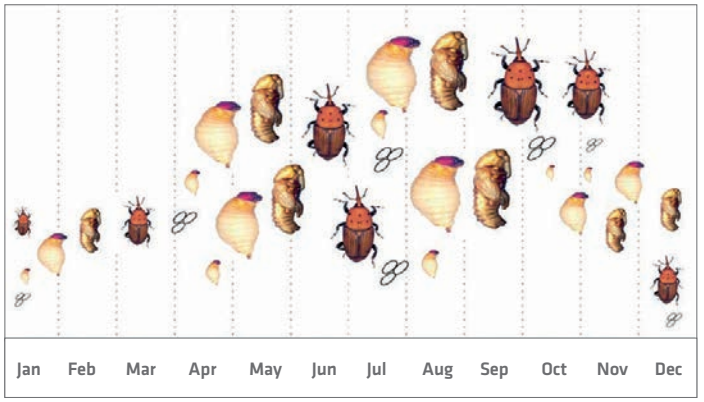


Fig. 11 Biological cycle of Rinchophorus ferrugineous. (By: P. Magazzini).
Fig. 12 Date collection after harvesting in Siwa oasis (Egypt). (Photo: P. Magazzini).

Overall country averages in the main production regions do not go much higher than 20-30kg/palm/year, though the production inputs are also less (fertilizers, pesticides) and generally the palms are spaced much closer. Even so, in well organized date plantations yields may reach over 100kg/palm/year under favourable environmental conditions. At the age of 30 years date palms reach the high-yielding period.

Nutritional values for 100 gm of dates	
ENERGY (calories) 250 Kcal	
Calcium	50-70 mg
Iron	1-2.7 mg
Magnesium	55-70 mg
Phosphorus	50-70 mg
Potassium	240-500 mg
Water	20-25%
Sugars	65-75%
Lipids	1-2%
Proteins	1.5-2.5%
Fiber	7-8%

TECHNICAL CALENDAR FOR A DATE PALM PLANTATION

Piero Magazzini

Technical calendar for planting tissue culture plants
Follow up during the first year and the following 3 years

First month

- debushing and levelling;
- layout of lines and rows;
- ripping (± 1.2 m) in both directions on the rows;
- install the irrigation system;
- Mark the exact position of plants;
- dig holes (0.6 m^3), if soil has been cross ripped or 1 m^3 if soil was not ripped, and leave open till end of Second month;
- distribution of old, well matured manure or any other organic material (i.e. maize hay, wheat straw, etc.) that will be used the next month.

Second month

- place the irrigation distribution system at plot level
- mix the well matured manure (3kg per plant), gypsum (if needed) and NPK fertilisers with the soil removed from the hole;
- put the mixed soil back in the hole;
- start the irrigation cycle 2 to 3 times to allow soil to settle. The decomposition of manure will be initiated.

Third month

- seedlings have been in the nursery for the past 8 to 12 months (depending on variety, their original size at reception from the laboratory, and on the care provided by the farmer). The plants should have been well irrigated (twice per week during winter and 3 times per week during summer;
- select your planting material at the nursery; only plants with at least 4 pinnae leaves are to be transplanted in the field;
- inspect your plants and make sure they are free of diseases and pests. In the future plantation, use the Integrated Pest Management Approach (manual or mechanical weeding, light traps, etc.);
- review and ensure the identification of each plant; where different varieties are being planted, use different colour labelling for each variety;
- each block, row and line is to be labelled. A map of the plantation (variety composition) is to be kept in the office (and/or at home).

Fourth month

February and March are the best months for planting (no wind, no extreme temperatures and the average humidity is about 40%).

- further another irrigation before planting is advised. Irrigate to field water capacity;
- recommended spacing is 10×10;
- planting should be done early in the morning to avoid transplanting stress, and irrigation should be done immediately after transplanting;
- bags should be cut from the bottom and progressively removed upwards, while the soil is put around the palm's substrate (to avoid root damage); all distorted or damaged roots are to be pruned;
- the leaf base of the palm should be clearly out of the surface of the soil; planting must be to the depth of the plant's greatest diameter;
- a basin of 1,5 to 1,8 m in diameter and 20 to 30cm deep is to be built for each palm. Hay or wheat straw is to be used for mulching;
- irrigation cycle depends on the location. However, we recommend 2 hours per cycle and with alternate days a week. From September till March the next year it should be increased to 3 cycles per week and 2 hours each cycle. The palm will hence receive 96 litres per hour.
- at all times, the soil near the newly planted palm should be kept moist through light and frequent irrigation;
- the irrigation cycle is to be monitored (using tensiometers if possible), and frequent check-ups are essential
- no leaf pruning is to be practised during the first two years (only leaves that touch the ground could be removed);
- the required number of male palms (5 for each ha) are to be planted separately in one block, preferably not in a windy spot and close to the pollen workshop;
- weeding is to be properly implemented.

Fifth month
- apply 250 g potassium chloride per palm;
- (six weeks after the planting date): apply 250g ammonium sulphate per palm.

Sixth month
- apply the second 250g potassium chloride per palm;
- assess your survival rate (should be at least 95%).

Seventh month
- apply the second 250g ammonium sulphate per palm;
- once the first year after planting is over, a fertilization program is to be applied till the first flowering year (year 4 or 5 depending on variety, location and provided care).

After 4 years, the farmer must implement the following technical calendar.

Technical calendar for a date palm plantation older than 4/5 years

April/May
- immediately after harvest, but no later than early May, the cleaning of the palms must be initiated. Old fruit stalks, leaves touching the ground and young offshoots are to be removed since they stress the mother palm, cause its decline and decrease fruit yield. No direct planting of these offshoots should be practised;
- they must be rooted in the nursery for at least one year;
- removal of spines from about 20 to 25 outside leaves and cleaning of the palms to prepare for pollination;
- leaves with symptoms of diseases need to be removed and burned;
- apply fertilization in April;
- apply potassium chloride fertilization in April;
- apply ammonium sulphate fertilization (in April and in May);
- if leaching is required, it must be practised before the start of the monthly fertilization;
- the palm's basin is to be weeded and mulched; and attend to the general maintenance practices such as inspection of all water points, mulching, weeding, repair of basins, etc.

June
- apply the ammonium sulphate fertilization;
- if male flowers start production, harvest the pollen and dry it;
- monitor a control plan against pests and diseases (avoid the extensive use of chemicals and base your approach on Integrated Pest Management; manual or mechanical weeding, light traps, phenomone traps, removal of diseased leaves, etc.).

July
- pollination season starts and will continue until the end of August, sometimes until the end of September;
- an adult male palm produces between 500g to 1,000g of pollen (an average of 700g), which is enough for pollinating 47 female palms; It is clear that 15g to 20g of pollen is the required amount of pollen to be used per female palm; approximately 2kg of pollen are needed per hectare;
- germination and humidity tests of stored pollen could be initiated at any convenient located scientific facility; if this is not possible try to use only fresh pollen;
- use mixed pollen (old and fresh); on daily basis, the pollen (just the quantity to be used) is to be mixed with non- perfumed industrial talc (or wheat flower) at a rate of 30% to 50% depending on varieties;
- medjool only requires a low quantity of pollen (10% pollen/talc ratio = 1:g);
- only skilled labourers should be used for pollination;
- pollination should only be practised between 10AM in the morning and 3PM (not before, nor after). A minimum temperature of 18°C is to be respected;
- if it rains within 2 to 3 days after pollination, repeat the pollination;
- to pollinate, the female spathes are to be gently opened after they start cracking; cover-sheaths will be removed with no damage to the inside flowers;
- the top 1/3 of the female inflorescence should be removed (1st thinning); do not squeeze the inflorescences while doing this;

- pollination should be applied at least twice with 2-3 day intervals (to ensure a good fruit set);
- in places where low temperatures are expected during the pollination season, craft paper bags are to be used to cover the pollinated inflorescence. Several days later (8-10), the bags must be removed;
- a slight leaf pruning could also be practised depending on variety and on the palm's canopy;
- make sure that the future enlarged inflorescence is not disturbed by surrounding leaves;
- apply ammonium sulphate fertilization in July;
- apply potassium chloride in July.

August

- continue pollination;
- two weeks after the last pollination, ensure a passage in each palm and below each inflorescence in order to assess the fruit set and to position (if a leaf or two needs to be cut, it must be done at this time); this is to prevent wind/leaf damage on the fruits;
- start marketing contact with potential date traders;
- ensure the availability of packing material;
- initiate logistical planning (storage, transport, etc.);
- apply ammonium sulphate fertilization.

September

Six to eight weeks after the first pollination, start the following:

- bunch removal: Limit the number of fruit bunches per palm to the accepted norms depending on the palm's age and vigour. Use the formula: an average of 10 leaves per bunch. The bunches kept are the ones with the nice fruit set and well equilibrated around the palm (equally distributed around the crown). One fruit bunch during first year of production, 2 bunches the second year, and so on;
- bunch thinning: Thin from the inside (± 1/3) but do not cut too close to the remaining inside spikelets;
- leave 5-6cm to avoid drying and fungal attack. Thinning is variety dependent and should be done only after precise evaluation of the fruit set;
- positioning and supporting the bunches: immediately after bunch thinning is completed for the whole plantation, the operation of positioning and tying is to be carried out. Be careful to gently position the bunch in order not to break the fruitstalk (use both hands). Each fruit bunch should be supported (to avoid its future breakage) by the use of two ropes attached to the upper and the lower leaf.

Note that all the above practises (pollination, thinning, etc.) are labour intensive (170 working days/year/hectare), and must only be handled by skilled labour. It is necessary to treat the flower/inflorescence with care from pollination till Hababouk stage.

- apply ammonium sulphate fertilization.

October/November

- apply the ammonium sulphate fertilization for October and November;
- all bunches are to be covered with net bags (80%) to protect the fruits from birds, wasps and insects. This period should correspond to the passage of fruits from Kimri to Khalal. Fruits at this stage are starting to turn yellow in colour (case of Barhee variety) and the nets are to be left on the bunches till fruit ripening and harvesting. This protection operation must be completed throughout the whole plantation before the Rutab stage is reached.

December/January

- observe irrigation scheduling;
- apply potassium chloride fertilization in January.

February

- if necessary, all dried and half dried leaves could be pruned during February to avoid the Rutab fruits from damage caused by these leaves during windy situations. It also helps the harvesting operation.

Afforestation area. Oasis ecosystem reconstruction and the productive nursery

Planting and protection of the new seedlings. (Photo: J. Nakhulo).

Lorenzo Vallerini

The typical plant associations of the palm grove in the oasis of Loiyangalani are dominated by groves of *Hyphaene compressa* or Doum Palm[1] and in the areas not yet destroyed by wild grazing (in other words in those areas protected by enclosures), by a sort of undergrowth composed of various species of bushes and open spaces covered by annual herbaceous species such as *Aristida mutabilis* and *Aristida adscensionis* with *Eneopogon* and *Cenchurs*. Unfortunately, in the eroded areas and in those that have been depleted of this undergrowth and grass by unsupervised grazing, an invasive species has taken over, *Prosopis juliflora* or Mesquite, which was imprudently imported and is difficult to eradicate.

The palm grove thins out in the areas without water, where the species that are typical of more arid zones or *Barrenlands* are found, with a prevalence of *Acacia tortilis* or Umbrella or White thorn.

Inside the oasis some specimens of palms are found (*Phoenix canariensis* and *Phoenix reclinata* or Wild Date Palm) and together with the Doum Palm, in the areas that are still intact, the so-called '*Loiyangalani Tree*' or *Sesbania sesban (l.) merr.*, (*S. aegyptica*) is found, also known as *River bean*, the *Ficus sycomorus l., Wild Fig,* or *Echoke* in the language of the Turkana, as well as *Salvadora persica*, very common in the whole Turkana area, the *Leucaena leucocephala,* an evergreen bush-tree, as well as a series of shrubs that have not yet been classified [2]

Although vegetation is scarce, it plays an important role in the life of the local population.

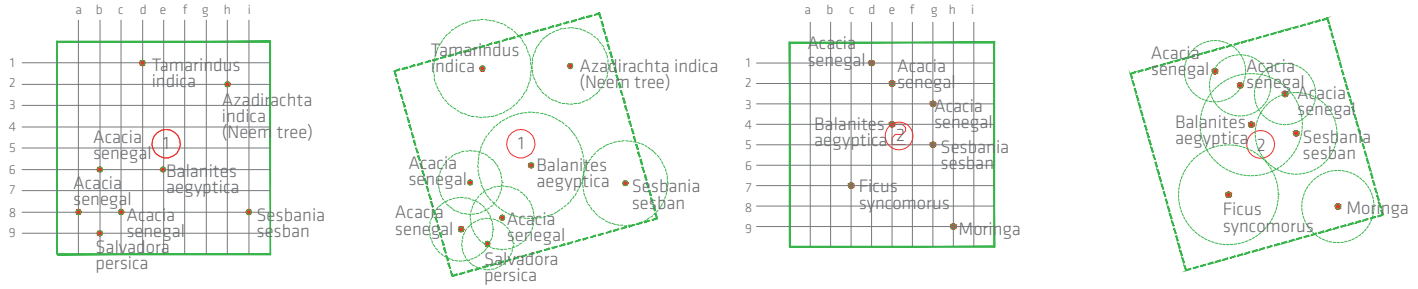
Plants are used for fuel, as construction material for the dwellings-huts, for building fences for livestock (camels, goats and some sheep) and as fodder. But not only, plants are also used for the production of traditional medicines and as source of vegetable fibres and gum arabic. *Acacia reficiens*, although not ideal, is the main source of wood for fuel and other uses, whereas the leaves and fruit of *Acacia tortilis* and the leaves of *Acacia mellifera* costitute the main source of food for livestock, together with *Salvadora persica*, *Acacia senegal*, *Cordia sinesis*, *Sericocomopsis hildebrandtii* and *Indigofera spinosa*; thorny trees, such as *Acacia* and *Commiphora*, are felled for producing '*boma materials*'[3], whereas those with softer wood, such as *Delonix*, *Commiphora* and *Erythrina* are used for making containers, bowls, cups.

The vegetation in the area is subject to a heavy pressure due to the increase in the local resident-settled population over the past ten years, both due to its use for fuel and for building new dwellings, in addition to its grazing by livestock and to the felling of plants for 'export' purposes. This increase in the use of the plant resources has reduced the greenery and increased desertification. Demographic growth and immigration have increased, and will continue to do so, the human population in the inhabited centre linked to the oasis and its surrounding areas, which also has the effect of reducing greenery and increasing desertification.

In the absence of balancing interventions (increase of newly planted vegetation and control of superficial erosion), desertification, which is also favoured by the reduction in rainfall, will continue to increase until the environmental balance, which in the case of an oasis is very fragile, is broken.

The only alternative is an intervention capable of inverting the trend, avoiding the use of easy shortcuts (the introduction of 'alien' plants, technology which is not compatible with the local traditions and know-how, etc.), while attempting to reconstruct as much as possible the natural cycles and the ecosystem of the oasis, in collaboration with the local communities.

Studies and research by the *World Agroforestry Centre*[4] demonstrate how also in Kenya the reconstruction of agro-forestall environments ecologically in balance plays an important role in the social and economic development of rural communities in terms of food, timber, fodder, etc. Yet in the current state, not only in Loiyangalani but al-



Module 2 (10x10 m.)
n.3 – Acacia Senegal; n.1 – Balanites Aegyptiaca; n.1 – Sesbania Sesban; n.1 – Ficus Sycomorus; n.1 – Moringa Stenopetala

Fig. 1 Forestry planting module 1. (By L. Vallerini).
Fig. 2 Forestry planting module 2. (By L. Vallerini).

so in other remote-rural areas of the country it is difficult to choose and obtain the necessary plants and trees for setting up nurseries, and even more difficult, due to the lack of theoretical and practical knowledge, to develop and maintain those already underway.

Thus, the first objective of this part of the project in the area of *Afforestation* was precisely that of providing information on which plants to use for extending the vegetation in the oasis, planting not only species which were already present in the palm grove when the ecosystem was whole and complete, but also using other species, albeit autochthonous to the north of Kenya, which could help to develop the vegetation system and offer an economic and productive benefit as well.

Naturally this part of the project was carried out in close collaboration with the Nursery of the Nanyori Area, where plants are cultivated for the Afforestation Area through seeds or cuttings from local plants, any already used in the previous experiences of the Nanyori Group. The species that were not available locally were imported from nurseries in Marsabit or Turkana Counties, or Nairobi.

The choice of plants, as mentioned earlier, depended on a series of practical criteria as well, that is plants which could also serve as source of nourishment or for the production and sale of products, including those relevant to the cosmetic-pharmaceutical field, such as the dates of the *Balanites aegyptica,* which are rich in protein, or the gum Arabic, which is obtained from the *Acacia Senegal* and used for most industrialized beverages, or the oil from the *Neem Tree,* which is used for making soap or cosmetics or against insect bites, the roots of the *Salvadora persica* for dental use (teeth whitener), the seeds and fruit of the *Tamarindus indica* for beverages and food, the leaves and oil of the *Moringa oleifera* (also known as 'miracle tree'), which are rich in nutrients, etc.

The Tutoring and Training stages, carried out by the Baraka Agricultural College, both in the Nursery of the Nanyori Area, with the planting and cultivation of plantlets, and in the planting of various species in the Afforestation Area following the plan established by the project, were fundamental, but it was only the beginning of a process which must necessarily proceed through time in accordance with a constant and continuous development program, at least during the two or three years following the end of the project financed by the EU (February 2018). This is necessary for ensuring an effective 'rooting' of the actions undertaken and for developing techniques and capacities not only concerning the production, but also the transformation of local products for their sale in the local market.

The planting strategy for the Afforestation Area took into consideration the following:

- the availability of water which can be carried from the collection tanks near the Palmeraie Area through pipes which pass under the road and the construction of a distribution point at the Afforestation Area; this was necessary for ensuring a minimum amount of irrigation during the initial stages after planting;
- the improvement of the fertility of the soil with the compost produced in the Nanyori Area;
- the construction of a system of fencing for protecting the plantation from animals and from the wind, using and incorporating into a single enclosure barbed wire, metal mesh screens (for preventing the passage of animals) and the 'marara' system made with local vegetation (for stopping the strong winds);
- the construction of a simple drainage system for preventing the washout of the soil in case of strong (and rare!) rainfall;
- access to the area during the entire year, both for expansion and maintenance work and, in the future, for the construction of small structures for the transformation of products.

Fig. 3 Planting map and irrigation system. (By L. Vallerini).

SPECIES Plant Distribution in Afforestation Area	N°	NURSERY
Acacia senegal (Gum arabic acacia) Turkana *Ekonoit* Samburu *Lolerikesi*	67	Kefri - Kenya Forestry Research Institute Nairobi Seed Centre
Balanites aegyptiaca (Desert Date)	22	Kefri - Kenya Forestry Research Institute Nairobi Seed Centre
Salvadora persica (Toothbrush tree) Turkana *Esekon*	12	Already cultivated in the Nursery of Nanyori Area in Loiyangalani
Tamarindus indica (Tamarindo) Turkana *Epeduru* Samburu *Roka*	9	Kefri - Kenya Forestry Research Institute Nairobi Seed Centre
Azadiractha indica (Neem Tree)	10	Already cultivated in the Nursery of Nanyori Area in Loiyangalani
Sesbania sesban or *S. aegyptica* River bean or 'Loiyangalani Tree'	19	Already cultivated in the Nursery of Nanyori Area in Loiyangalani
Ficus sycomorus (Sycamore Fig) Turkana *Echoke*	10	Kefri - Kenya Forestry Research Institute Nairobi Seed Centre
Moringa stenopetala (Moringa) Samburu *Lorsanjo*	8	Already cultivated in the Nursery of Nanyori Area in Loiyangalani
TOTAL NUMBER OF PLANTS	157	108 plants from KEFRI 49 plants from Loiyangalani

Endnotes

[1] *Hyphaene compressa (H.multiformis,H. thebaica)* or Doum Palm, is a palm which is native of the valley of the Nile in north-east Africa and which reaches a height of 18m. It is one of the few palms that stems from trunk into several regular branches. It is a handsome plant which adapts well to shallow soils, although it prefers areas were water is present. The fruit have a very hard shell yet are edible, although not particularly tasty, oblong or ovoid in shape and the size of a small tangerine, with a particular scent and taste and brown in colour. They come in large bunches. The leaves are often used for weaving the roofs of the local huts.

[2] Makishima H. 2005, *Flora and Vegetation of Nachola, Samburu District, Northern Kenya: A Study of Vegetation in An Arid Land*, «African Study Monographs», no.32, pp. 63-78.

[3] These are materials for building simple 'thorny' enclosures, but 'boma materials' also means basic or raw materials necessary for building objects, and in Swahili 'a form of fortified villages or camps'.

[4] Kehlenbeck K., McMullin S. 2015. *Fruit tree portfolios for improved diets and nutrition in Machakos County*, World Agroforestry Centre (ICRAF), Kenya; Mbora A., Lillesø J-PB., Jamnadass R. 2008. *Good Nursery Practices: A Simple Guide*. Nairobi. The World Agroforestry Centre.

PLANTS USED IN THE AFFORESTATION AREA

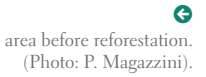
Lorenzo Vallerini

TREES AND SHRUBS	FAMILY GENUS | SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	MIMOSOIDEAE ***Acacia senegal (l.) willd.*** Gum arabic acacia Turkana language *Ekonoit* Samburu language *Lolerikesi* 12-15 m	Shurb or small thorny tree deciduous, drought-tolerant The tree is of great economic importance for the gum Arabic it produces to be used as a food additive, and as a cosmetic. New foliage is very useful as forage Dried seeds are used as food by humans An excellent fuel wood	Soil type: Varies from coarse-textured, deep sandy soils to dry, rocky soils, slightly acidic to moderately alkaline Semi-arid areas sometimes the only wood species to survive in dry areas. Very good growing capacity in Loiyangalani
	MELIACEAE ***Azadirachta indica*** Neem Tree 15-20 m	Medium size tree fast-growing that can reach up to 15–20 m tall. It is evergreen, but in arid areas can be semideciduos products made from neem have been used for their medicinal properties: to be antifungal, anti-diabetic, antibacterial, antiviral, contraceptive and sedative. Neem products are also used in selectively controlling pests in plants	The Neem grows on almost all types of soils including clayey, saline and alkaline soils, with pH up to 8.5, but does well on black cotton soil and deep, well-drained soil with good sub-soil water. Unlike most other multipurpose tree species, it thrives well on dry, stony, shallow soils and even on soils having hard calcareous or clay pan, at a shallow depth. Very strong to the arid climate. Very good growing in Loiyangalani
	BALANITACEAE ***Balanites aegyptiaca*** Desert Date 10 m	Small thorny evergreen tree Slow growing, generally narrow form. The yellow, single-seeded fruit is edible, but bitter. Many parts of the plant are used as famine foods in Africa; the leaves are eaten raw or cooked, the oily seed is boiled to make it less bitter and eaten mixed with sorghum, and the flowers can be eaten. The tree is considered valuable in arid regions because it produces fruit even in dry times. The seed cake remaining after the oil is extracted is commonly used as fodder in Africa Decoction of the root is used to treat malaria.	It is found in the Sahel-Savannah region across Africa. It can be found in many kinds of habitat, tolerating a wide variety of soil types, from sandy to heavily clayey, and climatic moisture levels, from arid to sub humid. Bush land Very good growing capacity in Loiyangalani

TREES AND SHRUBS	FAMILY GENUS | SPECIES LOCAL COMMON NAME	FEATURES MAXIMUM HEIGHT	NEEDS: SOIL, WATER, ROOTING, FOOD PRODUCTION OR OTHER PRODUCTS
	MORACEAE ***Ficus sycomorus*** Sycamore fig Turkana language *Echoke* 21 m (max. 46)	It is a large, semi-deciduous spreading savannah tree The fruit is a large edible fig, 2–3cm in diameter, born in thick clusters on long branch lets or the leaf axil. The bark is green-yellow to orange and exfoliates in papery strips to reveal the yellow inner bark. Like all other figs, it contains a latex.	Ficus sycomorus is native to Africa south of the Sahel. In its native habitat, the tree is usually found in rich soils along rivers and in mixed woodlands, but it can grow also in dry lands and Bush land Prefers deep, well-drained loam to clay soil rich in nutrients. Sandy soils with a shallow groundwater level may also be suitable. At Loiyangalani it grows only inside the Oasis
	MORINGACEAE ***Moringa stenopetala*** Moringa Samburu language *Lorsanjo* 10-12 m	Medium size tree deciduous fast-growing, drought-resistant tree, widely cultivated in tropical and subtropical areas where its young seed pods and leaves are used as vegetables. The fruit is a hanging, three-sided brown capsule of 20–45cm size which holds dark brown, globular seeds with a diameter around 1cm. and its wood is soft. The use of leaves and pods for animal fodder is currently of minor importance compared to their use for human consumption. It serves as a live fence in areas of its natural range	It is grown mainly in semiarid, tropical and subtropical areas, and tolerates a wide range of soil conditions, well-drained sandy or loamy soil. It is particularly suitable for dry regions It grows naturally in the Acacia tortilis-Delonix elata-Commiphora spp. vegetation-complex. This type of vegetation is often found in well-drained soils. The soil PH ranges from acidic to alkaline but mostly exhibit neutral reaction. Very good growing capacity in Loiyangalani
	RUTACEAE ***Salvadora persica*** Toothbrush tree Turkana language *Esekon* 6-7 m	It is an evergreen shrub or small tree very much common in the area. Its main trunk erect or trailing with profusely branched, wide crown of crooked, straggling and drooping branches; young branches green in color; bark slightly rough, greyish-brown on main stem, paler elsewhere. It has antiurolithiatic properties, used as a natural toothbrush, its fibrous branches have been promoted by the World Health Organization for oral hygene use. Research suggests that it contains a number of medically beneficial properties including abrasive, antiseptic, astringent, detergent, enzyme inhibitors and fluoride. The fresh leaves can be eaten as part of a salad and are used in traditional medicine for cough, asthma, scurvy, rheumatism, piles and other diseases. Leaves and young shoots are browsed by all stock. The flowers are small and fragrant and are used as a stimulant and are mildly purgative. The berries are small and barely noticeable, have a sweet, agreeable, aromatic, slightly pungent and peppery taste; they are eaten both fresh and dried and stored.	It grows in arid areas and in salty soils, but can grows also in clay soils, It is widespread, notably in thorn shrubs, desert floodplains, river and stream bank vegetation, and grassy savannahs. Prefers areas where groundwater is readily available, by riverbanks, on perimeters of waterholes, in seasonally wet sites, and along drainage lines in arid zones. Soil type: Prefers clays but is found on loam, black soils and sand. Adapted to alkaline or very saline soils, usually clay rich, and soils without salt. Very good growing capacity in Loiyangalani
	PAPILIONOIDACEAE ***Sesbania sesban*** (S. aegyptica) River bean or 'Loiyangalani Tree' 8 m	It is a short-lived shrub or small tree Deciduous and fast growing it is very good to improve the soil fixing the nitrogen These crops have had a long history of agricultural use, primarily as green manures and as sources of forage. The tree has a high percentage of foliage nitrogen and is an excellent supplement to protein-poor roughage in ruminant diets. Ruminants readily eat leaves and young branches. Its characteristics indicate the potential of the species as a high-quality forage source. It has been successfully fed as a sole diet to goats and as a supplement to low-quality forage for sheep	It grows along rivers and in areas rich of water, but also in acid soils and salty soils It shows some tolerance to moisture stress and tolerates soil alkalinity and salinity to a considerable degree. Tolerant water logging, and, both saline and alkaline soil conditions (Hansen and Munns 1985). Very good growing capacity in the Oasis of Loiyangalani
	CAESALPINIOIDEAE ***Tamarindus indica l.*** Tamarindo Turkana language *Epeduru* Samburu language *Roka* It can reach a height of 24-30 m, spread a crown of 12 m and develop a very large trunk of 7.5 m in circumference	It is a slow-growing, massive big tree, evergreen, deciduous in arid areas. Its extensive root system contributes to its resistance to drought and wind. The tamarind tree produces edible, pod-like fruit which is used extensively in cuisines around the world. The tender, immature, very sour pods are cooked as seasoning with rice, fish and meats. It is an important ingredient in chutneys, curries and sauces. The oil extracted from the seeds is said to be palatable and have culinary quality. Other uses include traditional medicine and metal polish. The wood can be used for woodworking. Because of the tamarind's many uses, cultivation has spread around the world in tropical and subtropical zones.	Very adaptable to arid areas it tolerates salty soils and it prefers well-drained alluvional soils. It is a long-lived tree with high resistance to wind dark-gray and rough bark and strong. T. indica grows well over a wide range of soil and climatic conditions. It prefers semi-arid areas and wooded grassland, and can also be found growing along stream and riverbanks. Quite good growing capacity in Loiyangalani


PROFILE N. 3
TREE NURSERY
0
5
10
20

Afforestation: planting and cultivation



Aspect of the area before reforestation.
(Photo: P. Magazzini).

Piero Magazzini

Soil cover and reforestation is a mechanism to protect soil from water loss. Like the protection of an umbrella, soil cover and reforestation protects the soil and the soil fauna within from the impact of sun heat, rain and wind. It stops the soil surface from sealing, and reduces the amount of precious rainwater that runs off.

As a result, soil cover both promotes and maintains optimum soil conditions for plant growth (nutrient availability) and water infiltration (water availability). Soil cover with living plants protects the soil surface from rain, wind and sun (FAO, 2005):

- It reduces soil erosion and protects the fertile topsoil, thus preventing the silting of rivers and lakes.
- It stops the soil surface from sealing, and reduces the amount of precious rainwater that runs off.
- It controls weeds by smothering their growth and reducing the number of weed seeds. This reduces the amount of work needed for weeding.
- It increases the soil fertility and the organic matter content of the soil.
- It increases soil moisture by allowing more water to sink into the ground and by reducing evaporation.
- Decomposing vegetation and the roots of cover crops improve the soil structure and make the clumps and lumps in the soil more stable – making it harder for rain to break them up and wash them away.
- Earthworms and other forms of life can prosper in the cover as well as in the soil.
- Soil cover stimulates the development of roots, which in turn improve the soil structure, allow more water to soak into the soil, and reduce the amount that runs off.

The Afforestation area is located on a flat ancient fluvio-lacustrine surface extending in the east area of the Loiyangalani Oasis, bordering the existing Doum palm forest on the west escarpment and the bare hill area to the east.

The area is about 3,379 square meter large on an almost flat surface with bare soils and sparse grass pillow that growing on thin sandy aeolian sediments.

Soils in the reforestation area are on a flat surface (Mapping unit 7), on lacustrine sediments, with light colluvial basaltic coarse materials coming from the upper basaltic hills erosion. Tree vegetation is absent up to the brink of the escarpment, where groups of doum palm occur, while the grass vegetation is composed by grassy pillows scattered on sandy sediments probably of aeolian origin.

The soils have a moderate profile evolution (An-Ab-Bk_BC-C), with A topsoil horizons on rough colluvial materials and more sandy textures, while the deeper horizons have finer textures, even clayey loam, with low salinity but high alkalinity. The fertility elements are usually rather defective, and should be integrated with local mineral or organic fertilization. The good capacity of water retention and the low salinitymake the area suitable for tree crops, being careful of removing the soluble salt that may appear on the surface horizons. The soils belong to the Calcaric Cambisols (Sodic, Alcalic) (FAO-WRB, 2006).

The Open Air Nursery- Afforestation project has planned to use several tree species, selected among the existing species in Loiyangalani Oasis and investigated during the last 2011 mission, and other species existing or used in the region of Lake Turkana.

The plant spacing is planned using two modules 10x10m large, with different distribution and spacing of tree species (2-6m from each others).

The species to use for reforestation are grouped in two groups depending on their qualities and growing requirements: the area has been divided in 31 modules, 15 belongs to the planting module 1 and 16 to the planting module 2.

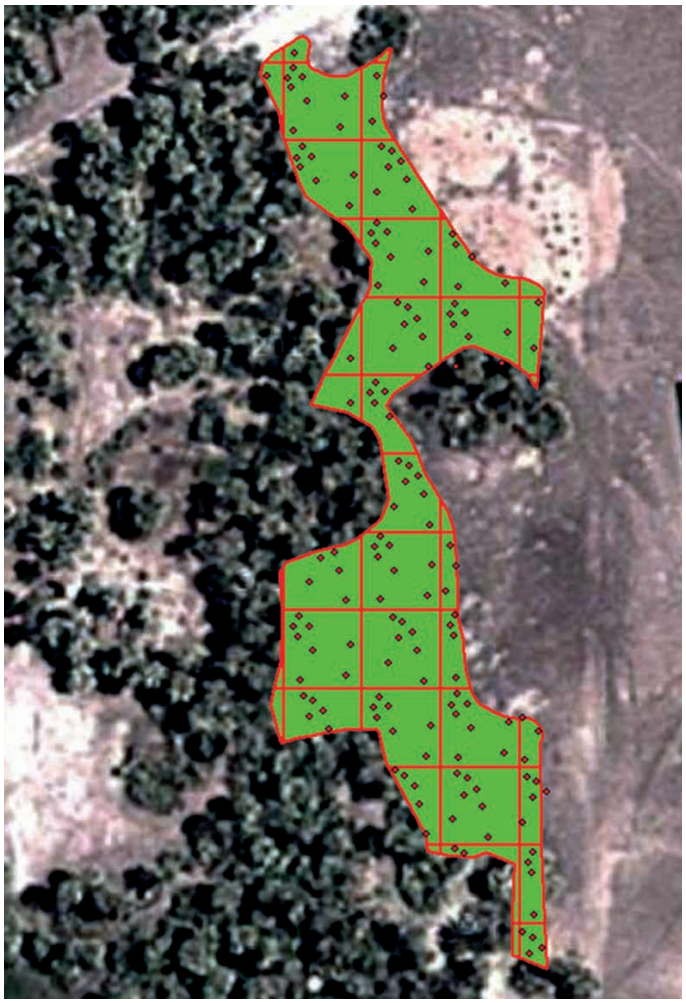


Fig. 1 Plant spacing and distribution in the Afforestation area (red dots). (By: P. Magazzini).

Fig. 2 Sicomoro tree. (Photo: P. Magazzini).

Module 1	Module 2
3 - Acacia senegal 1 - Salvadora persica 1 - Balanites aegyptiaca 1 – Tamarindus indica 1 – Azadiractha indica Neem tree 1 – Sesbania sesban	3 - Acacia Senegal 1 – Balanite aegyptiaca 1 – Sesbania sesban 1 – Ficus sycomorus 1 – Moringa stenopetala

The seedlings for the 157 plants planted in the area have been prepared in the different nurseries of origin, using seeds or taking a cutting to rooting, and, after a period at the nursery as necessary, have been transplanted in the Afforestation area when each plant had at least three permanent leaves.

The soil preparation included initial soil preparation that concerned mainly the preparation of the field such as debushing/bush clearing, removal of stones and rocks, ripping, leveling the soils, holes preparation, etc.

The young trees were planted in holes (90cm deep x 90cm wide) in order to put the roots in a soil horizons with a good retention water availability and with compost at the bottom. The holes were prepared two to three months before planting. After planting the young trees were watered daily for at least two or three weeks. With the objective to protect the trees and to improve the growth conditions young plants have been surrounded by fences (e.g. with cut date palm leaves or Marara).

In addition a coat out of straw and palm leaves has been put around the hole to reduce water loss.

After 1-3 months from planting, watering is no longer necessary, except in several dry periods in which some water additions can help trees to survive.

PHASES TO PREPARE SEEDLINGS AND TRANSPLANTING IN THE AFFORESTATION AREA							
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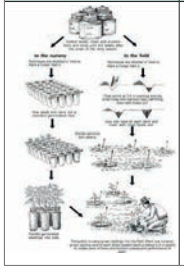
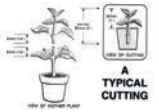
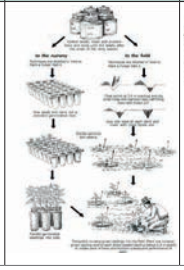
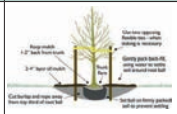
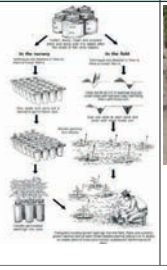
							

Vetiveria: pilot project for environmental recovery and fodder production

Women and Vetiver. (Photo: L. Vallerini).

Fig. 1 Vetiver area project, Plan. (By: L. Vallerini).
Fig. 2 Vetiver plantation layout detail. (By: L. Vallerini).
Fig. 3 Vetiver plantation layout detail 2. (By: L. Vallerini).

Lorenzo Vallerini

2017 was one of the years with most drought in north-east Africa in half a century. It seriously affected Somalia, Ethiopia, South Sudan and the north of Kenya[1].

Of the 1,5 billion people throughout the world who live in decayed lands where the soil is undergoing a process of becoming increasingly arid, in part due to climate change, and which bring about famine, instability and more or less forced migrations, a considerable part lives in this vast region characterized by a pastoral economy.

This obviously generated more or less serious forms of famine: millions of goat died, but also donkeys and camels, over a few months, from March to September of 2017 and consequently thousands of people saw their source of sustenance reduced to the minimum, which brought about the death of many, especially children and elderly, forcing entire communities to move to other nearby areas, often with scarce possibilities of survival.

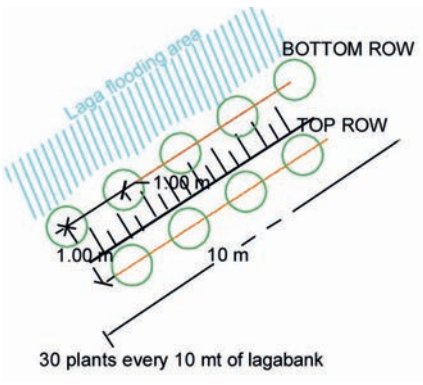
This scarcity of pastures generated as well conflicts among ethnic groups for increasingly reduced grazing lands. The most notable of which was precisely in Kenya, where conflicts erupted between farmers and shepherds causing the dead of approximately fifty people in the region of Laikipia, where the Italian-Kenyan writer Kuki Gallman was seriously wounded when she stopped some groups and their herds from entering the agricultural areas and the nature reserve run by her[2].

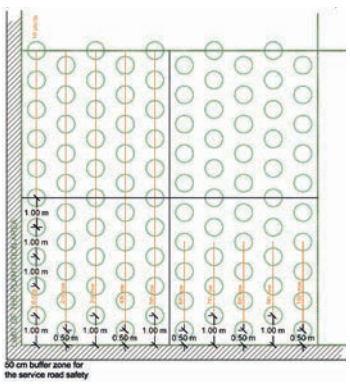
The problem is growing because there has been an increase in population, both human and in terms of livestock, among these ancient nomadic cultures which used to have large spaces where the resources were consumed before moving to a new area, perhaps following seasonal cycles and yet no alternative policies have been undertaken for providing sustenance for the animals. At most there have been the usual, albeit important, international aid programmes which, however, are limited to 'plugging the hole' only in the short term.

Loiyangalani suffered as well despite its great water resources; in fact, precisely due to the presence of water, it became a goal for many 'fugitives' from other areas, which increased human and animal pressure on the environment.

Nomads became sedentary and their herds graze on the scarce vegetation available in the areas near the oasis and along the shores of lake Turkana, which also provides the fish that ultimately completes the diet of the local population.

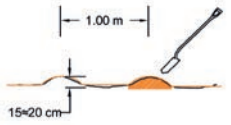
The Vetiveria project, which we have mentioned before, clearly does not provide an immediate answer to the problems in question, yet it proposes a plausible alternative for a long-term structural solution. It is an experimental, or pilot project which uses Vetiveria – it is a sterile plant, which does not reproduce autonomously and therefore is not invasive – for providing both food resources and for rehabilitating the environment in various areas surrounding the oasis.





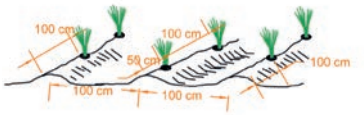
Vetiver generally needs 3-4 months to become estblished, sometimes up to 5-6 months under adverse conditions.
Since Vetiver is fully effective at the age of 9-10 months, mass plantings should occur at the beginning of the rainy season.

1) clear the surface from the stones;
2) level the surface



3) the plantation layout is made of rows, separated by draines.
The plantation rows must be 15-20cm high.
Note: use a hoe to make draines and bumps (one every meter).

4) plantation surface must be dug (one hole
every 100cm) to make the planning layout. The hole is 15-20cm deep and wide.
Note: look at the plantation holes.
The first row has the first plantation hole 100cm from the limit of the plantation area, the second row has the first plantation hole 50cm from the limit.



5) place plants (with 2-3 tillers apiece) in the centre of each plantation hole.
6) cover roots with 200-300mm (8-12") of soil and compact firmly.
7) water within the day of planting.

Fig. 4 Planting specifications. (By: L. Vallerini).

An area of approximately 8.000m² was chosen, next to the landing strip and already widely used for grazing and subject to the loss of topsoil and thus degraded, with the aim of:

- providing, in times of crisis, an additional food source as 'fodder'for livestock; not areas for free grazing but a cultivated area from which to prune the plants, following its growth cycles, in order to provide a plant mass to be distributed to the local shepherds; vetiver when pruned grows back swiftly, turning into a shrub approximately one and a half meters tall;
- implementing the quality of the soil and favouring the growth of other local herbaceous species, such as *Desmodium trifolium*[3]; Vetiver, in fact, does not only adapt well to saline and difficult soils, and does not have high water requirements, but also enhances the soil and favours the diffusion of other plants;
- provide productive opportunities, through the use of its roots, which can be used for the extraction of scents, medicinal oil, fibers for textiles, etc.

Vetiver, as mentioned before, has been widely used in many parts of Kenya since the beginning of the Eighties and is increasingly used both for the conservation of the soil and for enhancing the soil in tea plantations. This is also partly due to the fact that this plant does not compete with other plants and is entirely non-invasive[4].

Certainly, as with all other actions envisaged by this project, also that regarding Vetiver needs long and constant information and training activities in order to be properly carried out and integrated into local culture; then, if after a few years it will be ascertained that the project 'works', it may be necessary to regulate its common use within the community.

These are all processes which need time.

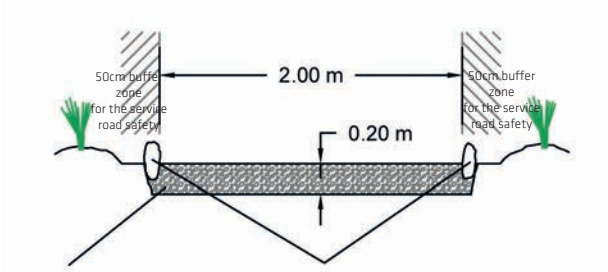
The area chosen for the Vetiver plantation was divided into three lots of approximately 2,000m² each, separated by dirt tracks which are necessary for work and harvest and enclosed with barbed wire and 'makuti' style woven palm leaves for protection from the wind and from the intrusion of livestock.

Approximately 2.400 plantlets imported from a nursery in Kitale were planted in the first lot with support from the scientific and professional association Plus Kenya[5] which not only provided the plants, but carried out training courses and practical training activities on site, in accordance with the guidelines of our project, which involved many locals during the planting activities for the first lot, and providing instructions on how to carry on with the work.

The one-week training programme involved approximately fifteen workers hired before the planting phase for the operations of preparing the soil, cleaning and setting-up the water supply system, and after this for the planting stage itself, as well as another fifteen to twenty people from the Nanyori Group and representing the local ethnic groups (El Molo, Rendille, Samburu, Turkana), both concerning practical and demonstrative activities and work on field on related issues:

- planting-harvesting (theory and practice);
- vegetative multiplication and nursery management (theory and practice);
- use of leaves as animal feed for livestock (theory and practice);
- uses of the roots for production of other goods (theory)[6].

Work continued until the final delivery of the project, with alternating phases, both for the diffusion of the new plants to be planted in the other two lots, and for issues related to irrigation during the first month after planting (lack of water) and to phenomena concerning



GRAVEL 0.20m
To make roads dig the surface for about 20cm and fill the excavation with gravel (for 20cm)

STONES FROM SOIL PREPARATION
Side of the road: make the line with a kerb of stones, the stones must be 10cm deep in the ground

Fig. 5 Path construction detail. (By: L. Vallerini).

Fig. 6 Vetiver plots just after planting. (Photo: J. Nakhulo).

Fig. 7 Vetiver mature cultivation in the area. (Photo: M. Folini).

vandalisms to the fences and subsequently the intrusion of goats which grazed on the young plants, which resulted in a delay in their growth. This happened during the periods of drought in 2017.

Whereas in other areas of the project specialised companies were contracted for construction works, in this case, as well as for part of the work related to the Palmeraie and the Afforestation area, activities were carried out on a 'time and materials' basis, that is hiring specialised labour (bricklayers, carpenters, etc.) and 'casuals', hired from time to time for specific stages of the project. Other locals were involved by the Nanyori Group both for work on field and for training activities, in the hope of an increasing participation of the local communities.

This is undoubtedly an experimental phase which, after the initial worries and resistance from the local authorities regarding the danger of invasiveness of Vetiveria, has obtained a general acceptance in the County and in Loiyangalani.

However, there is still some resistance from the locals to the idea of having to cultivate food for feeding their animals.

Endnotes

[1] Del Re P. 2017, *Etiopia*, «La Repubblica», March 7th and June 3rd.

[2] Veronese P. 2017, *La guerra nel paradiso terrestre*, «La Repubblica» April 24th.

[3] Desmodium is a genus of plant from the family of the Fabacee (or legumes) which includes dozens of varieties, most of which are herbaceous species. *Desmodium uncinatum*, a legume which is a native of Africa, is an insect repellent, is capable of fixing nitrogent and therefore to enhance the fertility of the soil, and is also excellent fodder for livestock. *Desmodium trifolium* is widely used for pastures and resists well to intensive pruning. It's only drawback is that it is invasive.

[4] Pinners E. 2013, *Vetiver History in Kenya*, November, 30th.

[5] Plus Kenya – Platform for Land Use Sustainability Kenya – is a Kenyan organisation with headquarters in Nairobi, constituted by a network of researchers, professionals and farmers committed to activities concerning *Land and Water Resource Management* from a standpoint of environmental sustainability which collaborates with many NGOs, CBOs, as well as with public entities, both Kenyan and foreign, with Univeristies and research centres and with private entities. It is a member of the Vetiver Network International and is very active in the diffusion of the uses and knowledge regarding Vetveria. Available online at https://sites.google.com/site/pluskenya/.

[6] Wegesa J. B. 2016, *Vetiveria zizanoides planting and management techniques training in Loiyangalani, Laisamis Sub-County of Marsabit County,* Plus Kenya Report, June, 24th.

Cultivation of Vetiver: methods and uses

Fencing and protection of the cultivations. (Photo: L. Vallerini).

Piero Magazzini

Vetiver grass (*Vetiveria zizanioides*), recently reclassified as *Chrysopogon zizanioides*, is a non invasive and a pioneer species able to establish degraded sites where under normal circumstances it is impossible for the latter to develop.

Vetiver grass has extremely good roots that can penetrate through hard pans and other difficult soil layers and types. This results in better drainage and better flushing of sweet water desalination of surface salts.

It improves soil moisture by reducing the rate and velocity of rainfall runoff; it protects stream banks, and removes unwanted toxic chemicals.

Vetiver has other attributes that impact the environment. Because of it great root mass it makes an excellent atmospheric carbon sink, and if grown on a large enough scale could qualify for carbon offset credits.

Other qualities of Vetiveria grass:

- Thrives under water logged conditions.
- Grows well under extremely adverse conditions such high salinity, high acidity and alkalinity and sodicity (Truong & Baker, 1998).
- Has high potential biomass production under nutrient rich condition such as effluent, 132tons/ha/year with 3 monthly harvests (Truong & Smeal, 2003).
- Has higher water use rate than, 7.5 times higher than Typha under wetland conditions.
- Is sterile and producing no seeds therefore no weed potential.
- Can be easily eradicated by uprooting.
- Is a good animal feed for livestock.

Environmental Vetiveria requirements

Vetiver grass is adapted to the tropics and subtropics. It is native to the tropical and subtropical areas of the Indian Subcontinent (India, Pakistan, Sri Lanka) and Indo-China (Indochina, Myanmar, Thailand.

It is adapted throughout the Pacific Islands and Caribbean Areas. In Hawaii, where farmers grow crops over a wide range of elevations, vetiver grass appears to be adapted from sea level to about 4,000 feet. However, in trials at locations above 2,000 feet it had slower growth and a lower rooting percentage of slips.

Established vetiver grass plants have been known to persist in areas with annual rainfall from approximately 20 to 200 inches.

Below 35 inches they may need supplemental moisture, particularly during extended dry seasons. Vetiver grass will grow on a wide variety of soils from sands to sandy loams and clays.

It will grow on strongly acid to slightly alkaline soils with a pH range from 4 to 7.5; however, it prefers neutral to slightly alkaline soils.

It tolerates saline soils and a range of heavy metals in the soil.

Soils

The vetiveria plantation project is located on the lower recent fluvial terrace (Land Unit 11), slightly elevated from the actual fluvial bed. In this area are diffused bare soil with scattered grass vegetation and spotted group of Doum palm. Soil are less developed showing the recent fluvial origins with several fluvial layers. Has sandy loamy or loamy sand texture, with many rock fragments (medium or coarse basaltic gravels) on surface and inside the soil. Structure is normally less developed or absent, soil reaction is still high, more than 9.0 and salinity on surface is low but increasing with depth. Alkalinity is high in all the profile up to 100cm from surface and organic matter content is weak or loose. Cation exchange capacity (CEC) is very low, so the fertility level is low. A little amount of humidity in the soil is present starting from 1 m from the surface. This quality of the land,

Fig. 1 Vetiveria plantation 3 years old. (Photo: P. Magazzini).

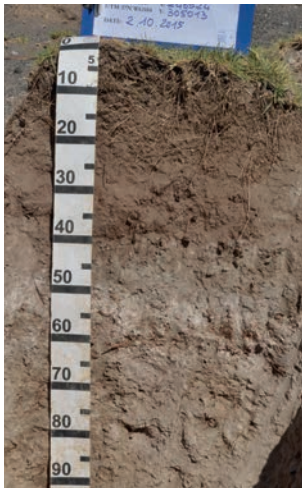
Fig. 2 Soil profile in Vetiveria area. (Photo: P. Magazzini).

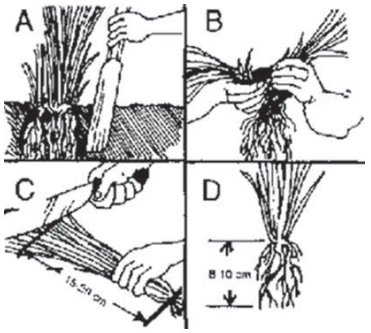
Fig. 3 Vetiveria multiplication method. (Photo: P. Magazzini).

Fig. 4 Vetiveria plantation project with the plant spacing in plot 1 (background, satellite image 2013). (Photo: P. Magazzini).

Fig. 5 Vetiveria storage area before planting. (Photo: P. Magazzini).

Fig. 6 Plantation operations. (Photo: P. Magazzini).





adding to the moderate flooding risk during rainy season, allow to growth vetiveria as well. Soil belongs to the Calcaric Fluvisols (Alcalic, Sodic) (FAO-WRB, 2006).

Vetiveria is largely salinity and alkalinity tolerant, sandy soils are good to develop Vetiveria, and the adult plants will give a good protection for soil erosion by flood and rain. At adult stage roots can penetrate up to the capillarity zone upon the water table (about 3m deep) to provide water for growth, but during the first stage after plantation, will need to provide a daily water supply. Also, in the first stage, will need to provide a light organic matter fertilization, at adult stage the plants will provide by ourselves organic matter with old leaf mulching.

Propagation

Cultivated Vetiveria is almost sterile, so seed propagation is not possible. Three methods are used to propagate Vetiveria, of which the most common is by roots division:

Multiplication by Stem-culm Cuttings

No matter how many nodes, mono-, bi-, or poly-node, are contained in a culm, old culms from the first four nodes in the base part of a stem have the highest survival rate, which goes up to about 50-60%; whereas the culms from the 5-6th nodes only have a 20-30% survival rate. The further the culms are from the base, the lower their survival rates, eventually to zero. In the same nodes, those which are deprived of sheaths and have revealed 'bud-eyes' and 'root points' sprout more rapidly, and produce more roots, than those which are not deprived of their sheaths. This is because the bud eyes and root points in culms whose sheaths are peeled off are capable of contacting directly with moisture in soil, which promotes root points to stretch and bud-eyes to sprout. If older cuttings are put in sand with saturated water, they will show 'white dots' next day, and produce new roots in the third day; if younger cuttings are used it will takes more than 20 days, but they do not become dry or dead.

Multiplication by Pedicel-culm Cuttings

During the period of flowering, pull open leaves lying next to the 5-8th nodes, and cut off the pedicel from the top 3-4 nodes. Over 5-6 days after the top is cut, prune the pedicel culm at 1-2cm from the

ground. Divide each node of the pedicel into one section, then dip the sections into 0.01%km in 04 solution for 5-10 minutes. After that plant them in a nursery. The nursery should well drained and fertile, water sufficient, and be in the shade. Irrigation is given 2-4 times per day, new roots will grow out some 10 days after planting.

Multiplication by Longitudinal-slit Stems

This method is interesting. Vetiver stems have opposite axillary buds and radicles. If a strong stem is longitudinally slit into two halves, then both can produce new tillers and roots. Longitudinal-slit seedlings should be cultivated in shade and the management must be meticulous. It is necessary to usually irrigate the bed in order to keep it wet. New roots will appear after stems have been transplanted for 6 days, and their establishment rate may be up to 100%. Furthermore, the propagation with longitudinal-slit stems has a pretty rapid tiller-formation; and can enhance multiplication speed by 2-5 times as compared to non-longitudinal-slit approach.

Multiplication through Pruning Tops

This is a quite novel approach. The main operation is as follows. Cut the top from the growth point when the plant grows up to 5-6 nodes; the purpose is to control top growth. Then peel off sheaths node by node to accelerate axillary buds aging. After top pruning and sheath removing, nutrients in plant will concentrate chiefly on the buds, thus new seedlings are beginning to sprout from the buds in 1-2 weeks. When the seedlings grow up to round 20cm, pick them up with the mother buds and culms together. Then heel in them under shade to produce roots as soon as possible. After new roots come out in about one week, they can be transplanted. This propagation method usually has a establishment rate of over 95%, and its speed of forming seedlings is far greater than propagation by pedicel-culm cuttings.

Soil preparation and planting

The mechanical or initial soil preparation concerns mainly the preparation of a field for plantation, hole preparation, etc. Actions, if applicable to the area, include:

- debushing/bush clearing;
- removal of stones and rocks;
- ripping; and levelling of the soil.

The project for Vetiveria plantation was planned in three steps, according to the plant availability and the climate requirement for plantation. The area is divided in three different plots, starting from north to south, as better described in the following table. The plantation started from Plot A using bare roots plants with spacing 05m on the row and 1m between the rows.

Plot	Surface sqm	Plants n°
1	2579	2138
2	2220	1875
3	1523	1051

After leveling the ground, started to design the plots with rows spacing 1 m to each other. Plant, after one day storage on the site with constant watering, has planted on the rows spacing 50cm between each plant.

Fig. 7 Vetiveria area after plantation. (Photo: P. Magazzini).

Fig. 8 Vetiveria water after plantation. (Photo: P. Magazzini).

Fig. 9 Some of common Vetiveria uses. (Photo: P. Magazzini).

Growing Vetiveria and irrigation scheduling

After plantation, Vetiveria need a constant daily watering for about one months. After that, the plants can grow without any other human supply.

Within 6 months, the first leaf production will be available for harvesting as forage for animals (goats, cows and camels).

If the season is too dry, it is possible to add a little amount of irrigation water one time a week.

Vetiveria harvesting and utilization

After about six months, Vetiveria leaves are ready for harvesting.

The utilization of Vetiveria for animal feed MUST be only for forage and not by direct pasture, it is therefore necessary to harvest the leaves manually and distribut them fresh to the animals.

As animal feed Vetiver leaves are tasty fodder readily eaten by cattle, goats and sheep. Table 2 compares Vetiver's nutritional values to those of other subtropical grasses in Australia. Young Vetiver grass is quite nutritious, actually comparable to mature Rhodes and Kikuyu grass. However, the nutritional value of mature Vetiver grass is low, and it lacks crude protein.

Description	Units	Vetiver grass			Rhodes	Kikuyu
		young	mature	old	mature	mature
Energy	Kcal/Kg	522	706	969	563	391
Digestibility	%	51	50	--	44	47
Protein	%	13.1	7.93	6.66	9.89	17.9
Fat	%	3.05	1.30	1.40	1.11	2.56
Calcium	%	0.33	0.24	0.31	0.35	0.33
Magnesium	%	0.19	0.13	0.16	0.13	0.19
Sodium	%	0.12	0.16	0.14	0.16	0.11
Potassium	%	1.51	1.36	1.48	1.61	2.84
Phosphorous	%	0.12	0.06	0.10	0.11	0.43
Iron	mg/Kg	186	99	81.40	110	109
Copper	mg/Kg	16.5	4.0	10.90	7.23	4.51
Manganese	mg/Kg	637	532	348	326	52.4
Zinc	mg/Kg	26.5	17.5	27.8	40.3	34.1

Vetiveria is not only a source of fresh grass for animals, but all parts of the plant (leaves, roots) can be used in several ways, as following described:

- *Erosion control:* A vegetative barrier is a dense hedge or row of plants growing on or near the contour. Vetiver grass is well adapted to the vegetative barrier used to control erosion on farm land because of its strong, compact root system and numerous stiff stems.

- *Phytoremediation and bioremediation:* Vetiver grass has been shown to enhance the degradation of heavy metals such as aluminum, cadmium, chromium, copper, lead, and nickel and polycyclic aromatic hydrocarbons in the soil.
- *Perfumery:* Vetiver grass roots contain an essential oil that has been known in India since ancient times and considered a high-class perfume.
- *Other uses:* A traditional medicine; an ingredient in curry; the roots are woven into various articles such as baskets and coarse mats and screens which are fragrant when wet; a biomass fuel for generating electricity; as ornament.

VETIVERIA - STEPS OF PLANTATION OPERATIONS

1. Plant purchasing trasnsportation and stocking in nursery

2. Soil preparation

3. Digging surface well for emergency irrigation

4. Plants preparation for plantation

5. Manure tea mulching

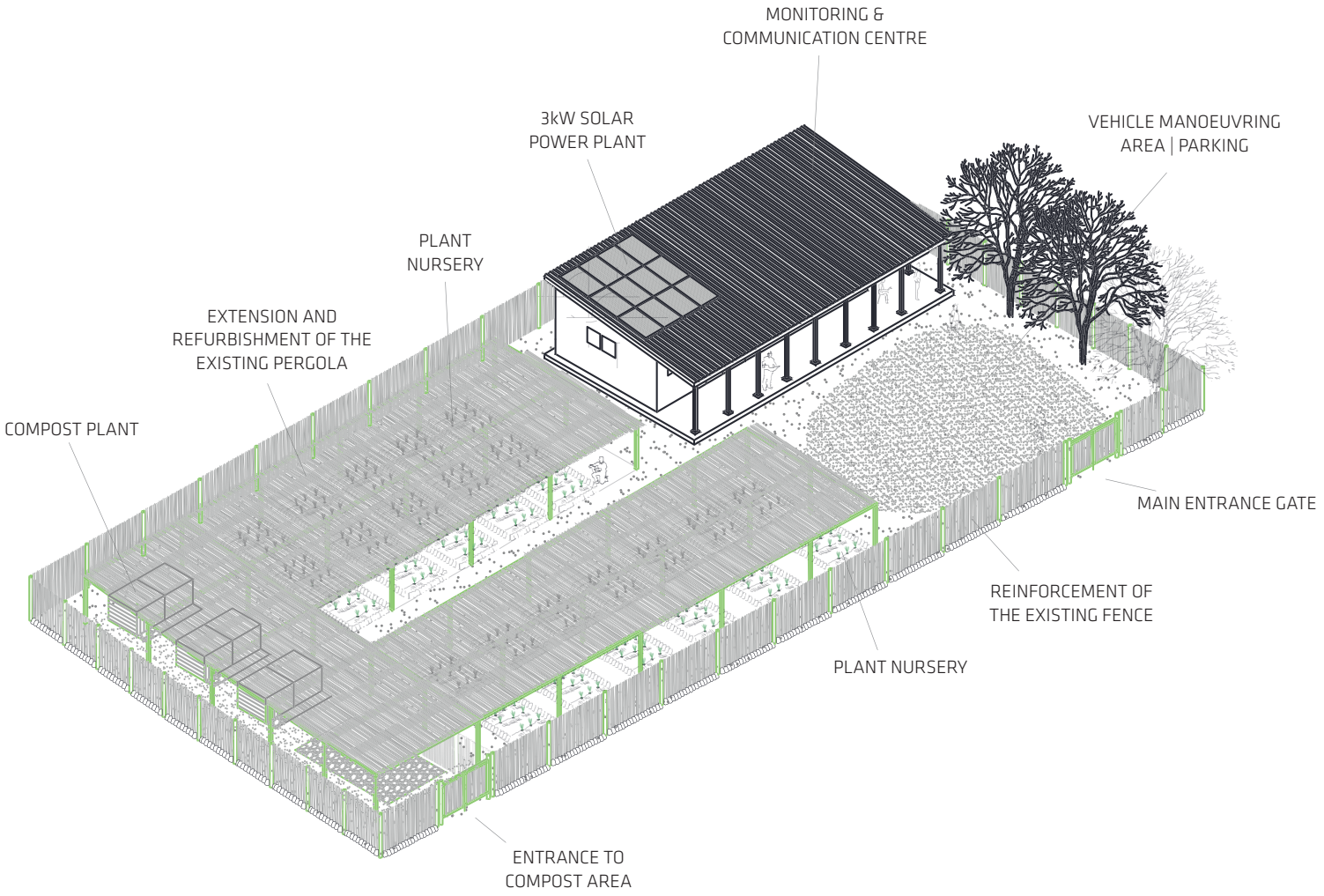
6. Plantation on site

7. Irrigation

8. Growing

9. Harvesting

10. Vegetative multiplication


MONITORING &
COMMUNICATION CENTRE
3kW SOLAR
POWER PLANT
VEHICLE MANOEUVRING
AREA | PARKING
PLANT
NURSERY
EXTENSION AND
REFURBISHMENT OF THE
EXISTING PERGOLA
COMPOST PLANT
MAIN ENTRANCE GATE
REINFORCEMENT OF
THE EXISTING FENCE
PLANT NURSERY
ENTRANCE TO
COMPOST AREA

Services

Axonometric projection of the Nanyori Area with the building of the M&C Centre, the Nursery and the compost plant. (By: L. Vallerini).

The monitoring & communication centre (M&C Centre), the nursery and the compost plant

The new building of the Monitor&Communication Centre. (Photo: L. Vallerini).

Lorenzo Vallerini

The project as a whole comprises five different areas, each with its own specific function and its innovative elements for reverting the deteriorating processes, both social and environmental. Each area is to be managed in different manners in accordance to the aims set, some experimental, from the beginning, yet due to this very variety of objectives it was necessary to envisage a coordination centre which would also be a place for interaction and for the diffusion and development of scientific and cultural education concerning these issues.

The Monitoring and Communication Centre was the answer to this fundamental need: a place for coordinating the various activities, as well as for gathering and generating interaction among the people interested in the project and for developing a common significance to the initiatives.

As mentioned earlier, the area that houses the centre, and which belongs to the Nanyori Group CBO[1], is approximately 800m^2 and is located in the Turkana village to the west of the oasis, an area which is in a phase of intense urban development. The Nanyori Group, which has been involved in the project since the beginning, is and will be the intermediary with the local ethnic groups and the service provider, both in the area which belongs to them, yet is open to the community, and outside of it.

The first step consisted in the building of a 'house' for the group and for the locals, to be provided with I.T. equipment and furniture for an office, a small library on Botanics and Agricultural technology, toilets, a small kitchen and a storeroom for tools.

Itis a 60m^2, one-storey building with a single-pitched roof, like most other buildings in the area, which extends into an L-shaped 36m^2 patio on both sides of the building and which serves not only as protection from the sun, but also for distribution to the various spaces of the structure without having to resort to corridors or interior passageways.

The construction of the building was based as much as possible on what the local labour market could offer and on a series of simple building techniques already widely used in other buildings in Loiyangalani, trying to implement them through modest enhancements and modifications.

The roof, placed on a south-eastern direction, holds a series of photovoltaic panels which provide energy for lighting, the pumps, appliances, computers, printer, etc., and was placed in a space between walls which ensures thermal insulation. In fact, although using the typical corrugated tin sheets for the roof, as used in all local buildings-huts (and all over Africa), it was considered fundamental to ensure thermal insulation, both for making living conditions inside adequate, and for providing the building with windows with glass panes which could prevent or limit the amount of dust coming in from the outside, which is particularly harmful to electrical appliances and computer equipment.

The walls were also built with a thermal insulation system, that is using 'core' walls with local limestone and an external metal mesh structure with wooden pillars which was then plastered; obviously the load-bearing structure was made with reinforced concrete on a strip footing foundation.

The building was also provided with a water supply system which pumps the water from the nearby public fountain and collects it in a tank placed outside the building and distributes it through gravity both to the building itself and to the three exterior taps for irrigation purposes.

The sewage system was also built using local technology which involves a system of settling and depuration of water (septic tank) before its dispersion on the ground, following national regulations.

Another important aspect of the centre involves the enlargement and reorganisation of the Nursery in view of a production system which uses simpler nursery techniques and the classification and

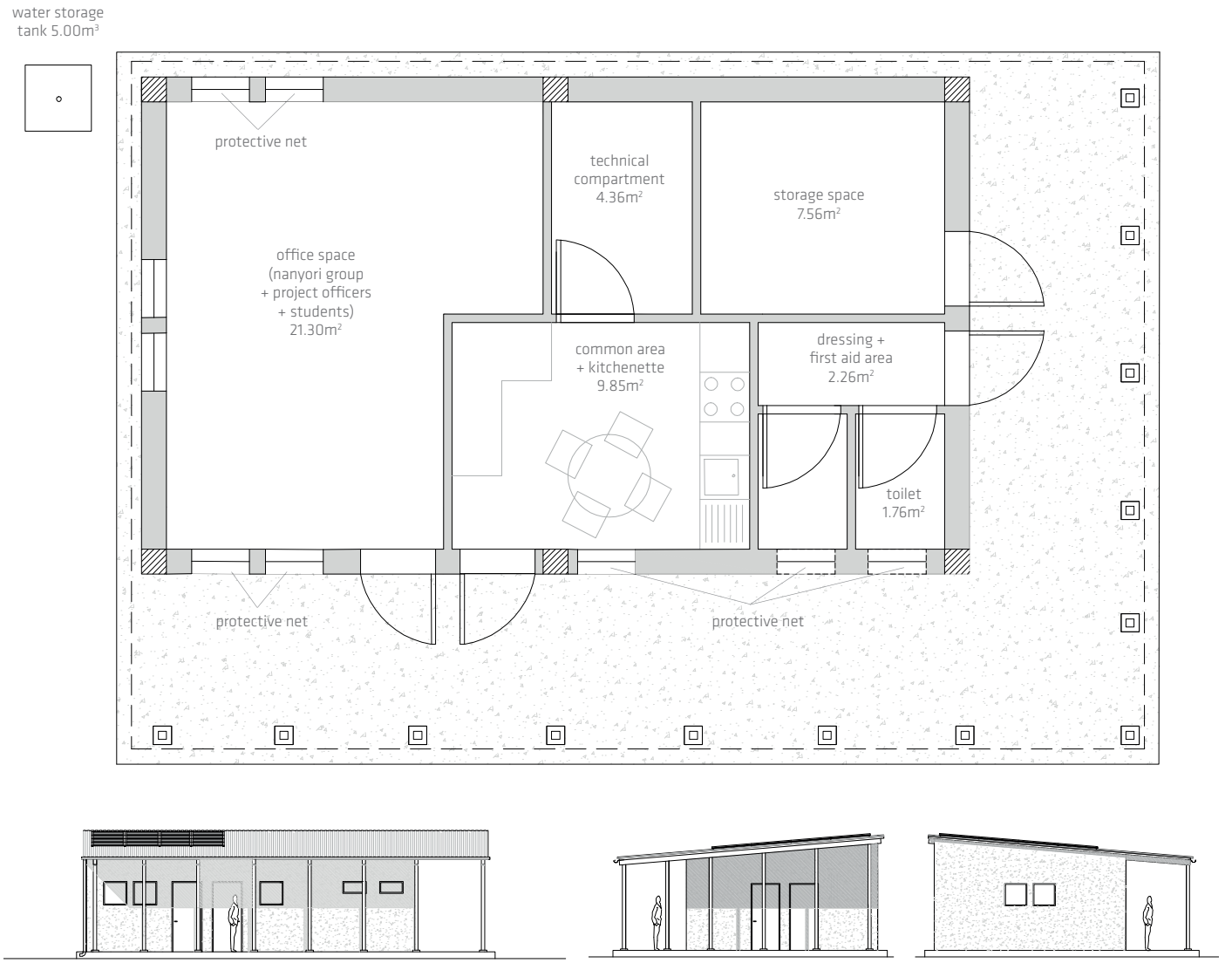


Fig. 1 Centre building-Ground floor map. (By: L. Vallerini).

Fig. 2 Front view. (By: L. Vallerini).

Fig. 3 East side view-West side view. (By: L. Vallerini).

cultivation of the various species and varieties necessary for the new plantations surrounding the oasis in the Afforestation areas. The *Small Nursery* has been located under an arbour approximately 250m² large for protecting the plantlets from the strong sunlight and for reducing evapotranspiration from the plants, which results in savings in terms of irrigation water. The existing arbour was partially demolished and rebuilt-reinforced with a new roof made with palm leaves woven in the local 'Makuti' fashion.

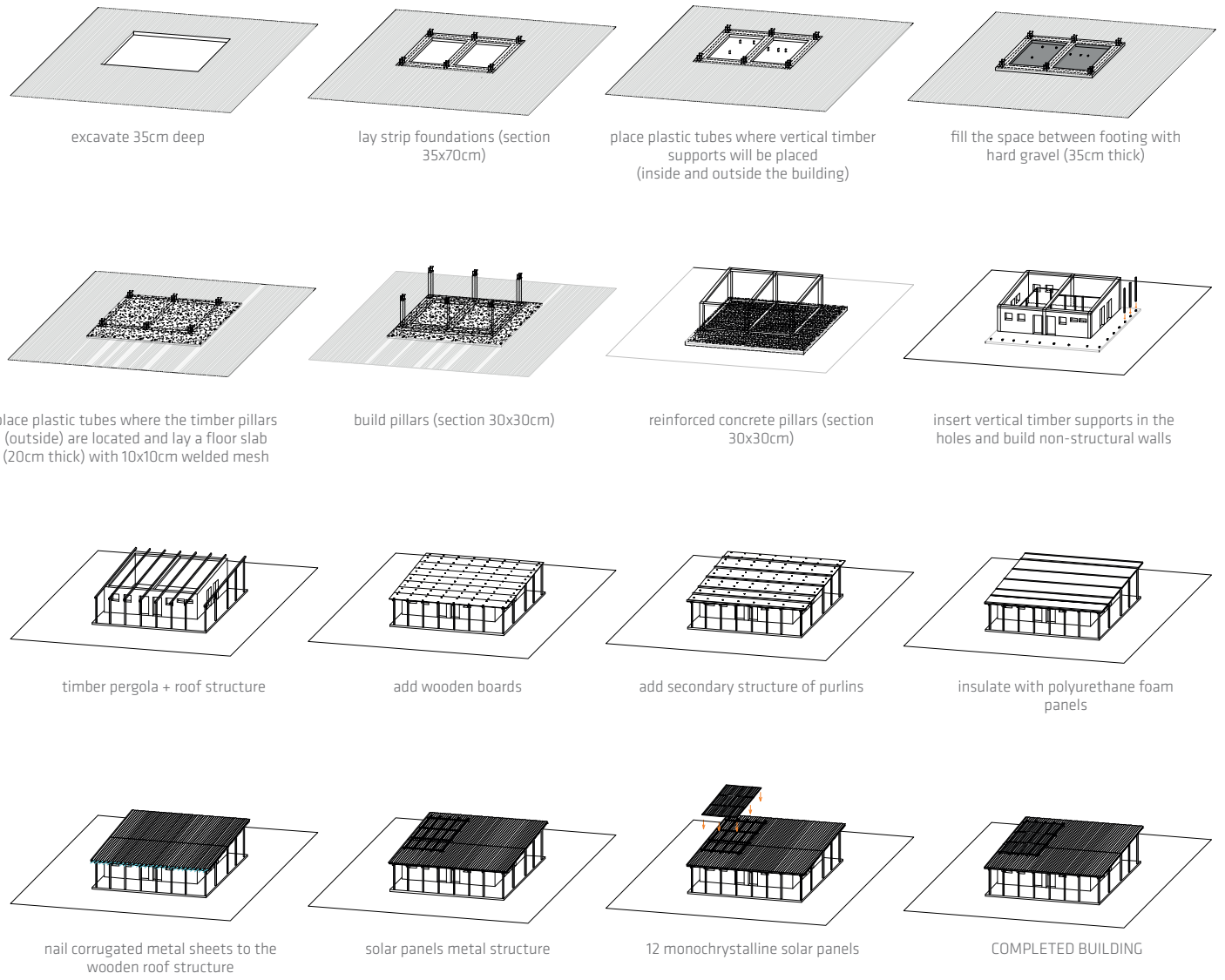


Fig. 4 Construction phases. (By: L. Vallerini).

Finally, and also under the arbour on an area covering approximately 120m^2, the *Compost Plant* was built and which will be run with manure and organic waste from the community; the compost has been used for all the new plantations, as well as for all plantlets grown at the Nursery.

Endnotes

[1] CBO or Community Based Organization is a nonprofit group that work at a local level to improve life for residents. Work conducted by a CBO is generally related to issues involving human services, natural environment conservation or restoration, and urban environment safety and revitalization.

Solar energy for the project

Local construction materials and systems.
(Photo: L. Vallerini).

Lorenzo Vallerini

The area of lake Turkana is an enormous reservoir of solar energy, but through direct sunlight, and indirectly from the strong winds.
The enormous aeolian power plant being built 60km from Loiyangalani (one of the largest in the world) is proof of the great availability of energy from the wind, whereas the energy derived from the constant sunlight, twelve hours per day and practically without clouds, remains mostly untapped, especially at a large scale.
Paradoxically, the area of Loiyangalani lacks an electricity supply network, which means that for many years now the only source of energy has been from electricity generators which run on fossil fuels, used mostly for certain public or tourism-oriented buildings.
During the past ten years the widespread use of photovoltaic panels for domestic use increased remarkably – as it has throughout Kenya, to the point of reaching the mark of 20MWp installed by November 2013[1] – with the installation of small solar plants, sometimes combined with aeolian generators capable of providing electricity on a 24/24 basis, and which often include accumulators.
A combined equipment of this sort was installed at the 'Dispensary' run by the Italian nuns near the church, fundamental for properly running medical equipment. Yet systems such as this were also installed in tourism-oriented structures and bars, not only for providing light, but also for refrigerators and for recharging mobile phones, which almost the entire population owns today. Even Safaricom, the mobile network operator, runs its antennas with aeolian power generators (which have however fallen into disuse because they suffered many malfunctions due to the strong winds) or with photovoltaic panels.
Regarding telecommunications and the production of electricity it can certainly be affirmed that over the past six to eight years there has been a considerable leap in terms of technology, even for a remote area such as Loiyangalani. This same development, however, has been absent in terms of the management of water resources and of the development of adequate water systems in view of the growing needs of the area.

Thus photovoltaic panels were considered as essential also for our project, both for the use of electricity at the M&C Centre and for the use of the pumps, which are necessary for drawing water from the new well, for the distribution system to the village, and from the springs in the oasis for the irrigation of the Palmeraie and Afforestation areas.

Production of energy for the M&C Centre

The building of the M&C Centre was provided with photovoltaic panels for the production of the electricity needed for running the equipment and for lighting. The following is a list of the appliances and equipment:

- 5 computers;
- 9 telephone chargers (+ other possible ones);
- 1 printer;
- 1 refrigerator;
- Lights: 10 large and small neon lights inside + 2 exterior lights.

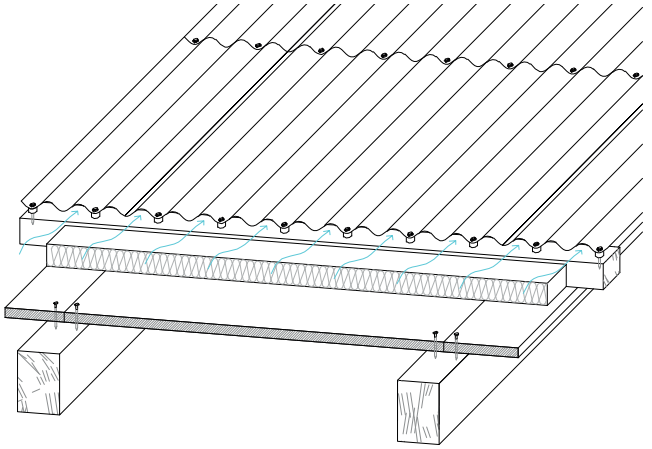
The photovoltaic system on the roof was placed in a south-west direction and supplied with batteries for night-time. It has a capacity of 3kW and consists of:

- n.12 monocrystalline photovoltaic panels, 320W each;
- n.1 5.000VA inverter;
- n.1 a protected junction box;
- n.1 battery box;
- cabling connecting the components and to the generator.

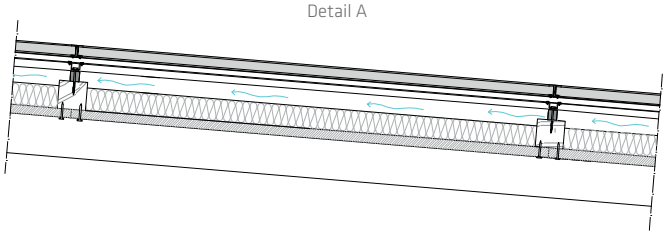
Pumping of water for the new well

The new well is supported by a 180W photovoltaic kit for drawing water appropriate for a hydraulic head up to 100 meters and consisting of:

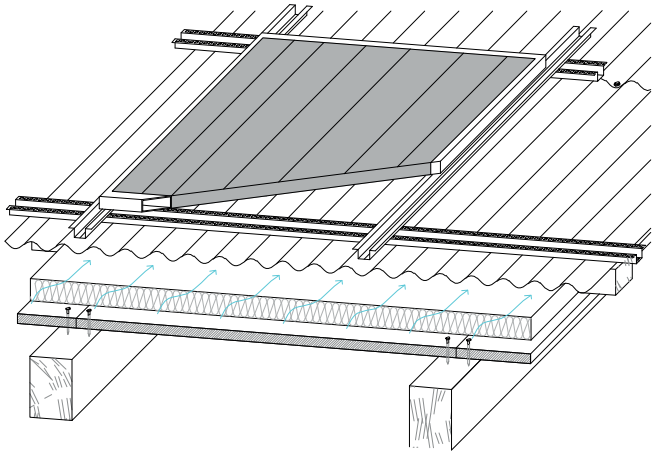
- 2 SYM90HP 90W/12V polycrystalline silicon panels;
- 1 SOLARFLUX cam 2 submerged pump;
- 1 MK2 controller;
- 1 Dry-Check protection device.



Detail A



Solar panel detail



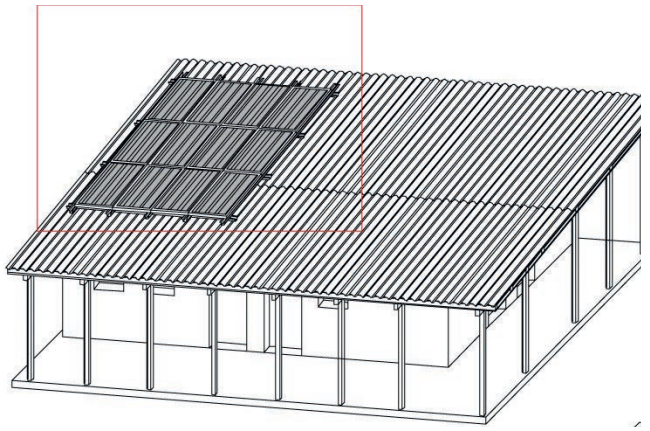


Fig. 1 Roof details and the solar panels. (By: L. Vallerini).

Fig. 2 Water distribution system. (By: L. Vallerini).

Fig. 3 Construction of the arbor. (By: L. Vallerini).

The system was devised for a direct use, without batteries: in this way the pump works only during the day and in ideal solar conditions. This system is particularly well adapted for filling tanks, cisterns and drinking troughs for animals.

In function of the depth of the water, the following flow rate can be obtained:

0 mt	25mt	50mt	75mt	100mt
3,400 lt/day	2,200 lt/day	1,600 lt/day	1,100 lt/day	820 lt/day
360 lt/hour	280 lt/hour	230 lt/hour	200 lt/hour	170 lt/hour

Our well is at a depth of 40m, which means that it has a maximum flow rate of approximately 300lt/hour.

The photovoltaic modules are installed on supporting structure placed on the roof of the two tanks which are in turn placed on a concrete structure on the raised banks of the *Wadi* at an adequate distance from the water drawing point so as to avoid energy dispersion.

The solar pump for the irrigation of the Palmeraie and the Afforestation areas

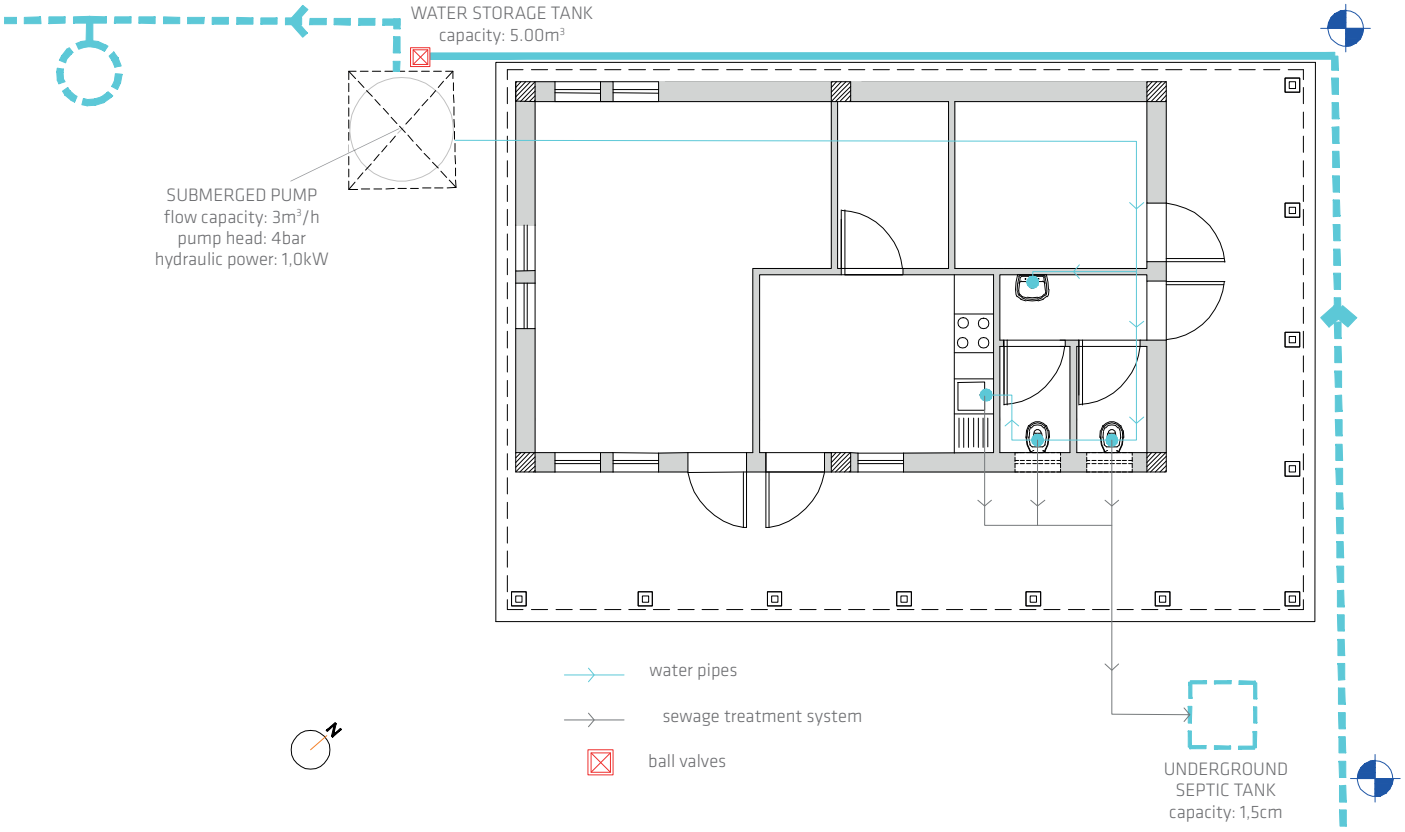
The system for drawing water from the springs in the oasis consists in a submersible pump with motor (minimum flow rate 15m^3/day, head required 35m. Dayliff PVC pipe, 35m cable) and adduction tubing which carries the water from the pump to the three 5m^3 tanks placed on a raised metal structure from which water flows by gravity into the artificial canals of the Palmeraie and of the hoses for irrigating the Afforestation area.

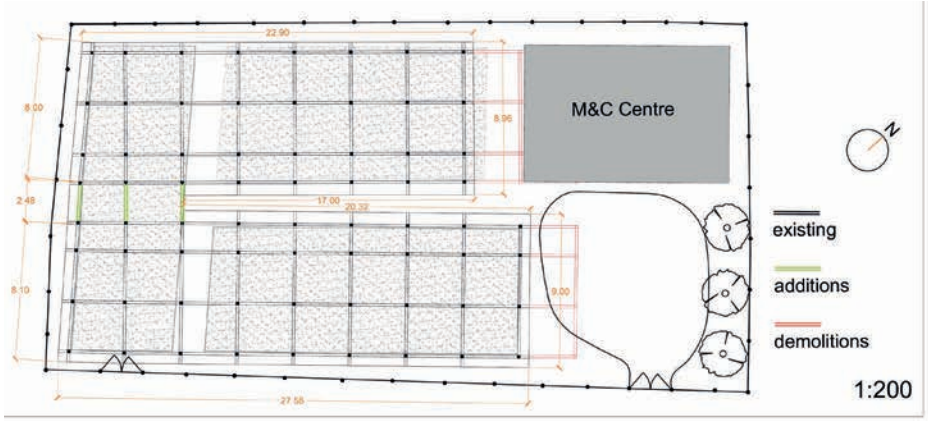
The energy for the pump is generated by two 320W photovoltaic panels and equipment such as:

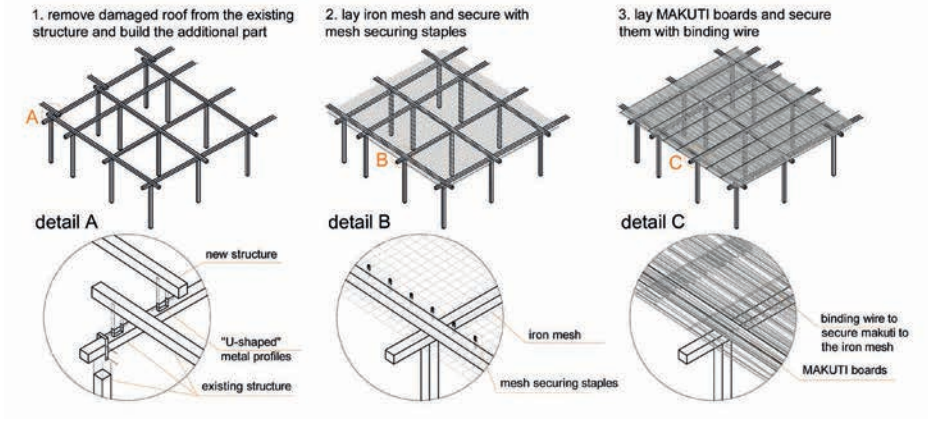
- an electrical system (switch with cable and connectors from springs to the tanks, tank overfull floating switch with 20m connection cable and connectors, water meter);
- a 5000VA Inverter;
- a field switchboard with protection of electrical installation;
- a box of electrical storage batteries for use during the night-time;
- wiring between main control panel and other components;
- solar module and pump controller;
- cables and connections from panels to the controller, sun switch safe.

Endnotes

[1] Hansen U. E., Brix Pedersen M., Nygaard I. 2014, *Review of Solar PV market development in East Africa*, UNEP Risø Centre Working Paper Series no.12.







Current situation

MAKUTI boards
approximate dimensions: 50x80 cm

Fencing system

The cultivations under the arbor.
Nursery production. (Photos: J. Nakhulo).

Lorenzo Vallerini

Man has always enclosed the living space surrounding his dwelling or larger settlements with various types of enclosures, used either for keeping out animals and intruders or for protection from adverse environmental conditions, such as wind, dust, surface waters, invasive plants, etc.

In shepherding and agriculture enclosures serve not only as protection from predators, but also for setting property boundaries and systems for protecting plants from livestock grazing and difficult climate conditions. Throughout the world these systems have created beautiful landscapes and systems for blancing the lack of water or for controlling extreme temperatures, both too cold or too hot.

Dry stone walls, brick walls, live hedges, dead log hedges, mounds of earth with stones and hedges, picket fences, etc., are found all over the world in all shapes and manners, made with a variety of materials available on site.

In arid and semi-arid zones these systems were also devised against desertification and for protecting gardens or oases form a hostile 'outside', for opposing sand or dust which covers all, for retaining the humidity that is available at night (in stones) in order to release it by day, for decreasing evapotranspiration in plants and for establishing a sort of microclimate which fosters greenery and coolness.

Among the various *Traditional Knowledges* encouraged and supported by the UNCCD and UNESCO, particular attention is devoted to systems for the protection and development of crops[1].

One example are the *dry walls* built using rows of stones that cover the brickwork with slabs slanted inwards in order to allow the humidity to flow toward the inner stones. These are in fact devices for condensing and gathering humidity with the added function of protecting the soil[2].

Or else the system for *erg* oasis formation[3] consisting in artificial craters and dunes which provide protection while vegetation obtains water directly from the ground creating a micro-climate which is favourable for cultivation.

Or, finally, the *dead log* hedge, which uses mounds of earth and dry plants woven with thorny bushes for protection from the wind and from animals, which also has the function of sand fencing, in which sand and dust are accumulated until they form protective dunes[4].

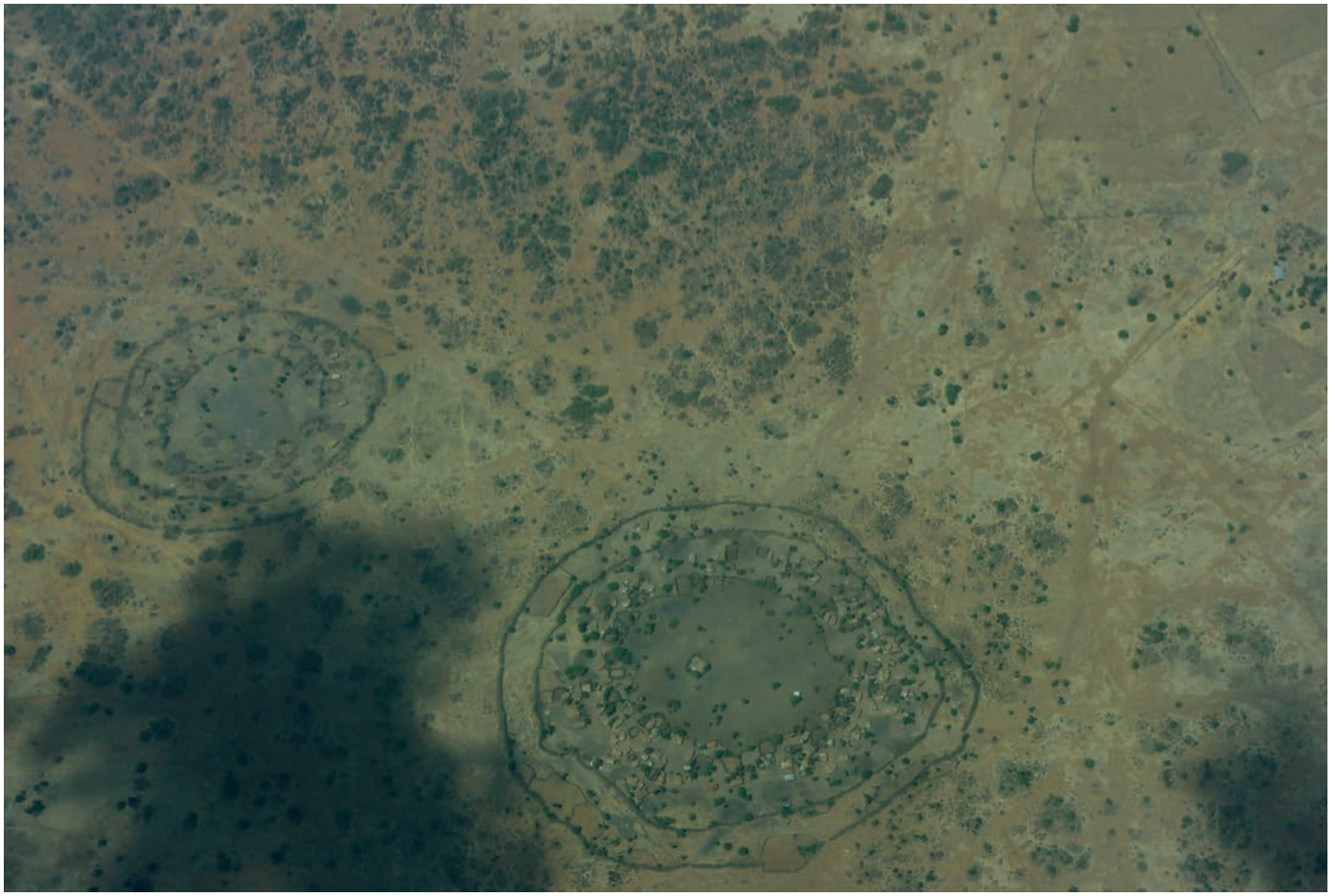
Dead log hedges are often made with dry leftovers from the pruning of cultivated plants which are then woven and tied using all sorts of techniques. In Tunisia *Palmeraies* plant leftovers after harvesting dates (palm fibre) are used by weaving them into strong ropes which are then used for tying the dry leaves together and building enclosures which break the dry wind and sand, thus protecting the palm grove.

For our project it was decided to use as much as possible the local traditional knowledge which is based precisely on the ancient craft of the local community, which consists in weaving the leaves of palms and other species for building their dwellings, both walls and roofs, with amazing effects in providing protection from high temperatures, dust and also somewhat the rain.

Variation in the building techniques of dwellings are manifold and vary from one ethnic group to another.

The El Molo use very particular building methods and the design of the hut is quite different from most other traditional dwellings in the north of Kenya: the hut in fact resembles an igloo and is made with leaves from the doum palm, which cover a wooden structure in the shape of a cupola covered on the inside with large animal hides.

The Turkana organise their settlements as a Kraal[5], that is around the enclosure for the goats and preferably near a tree, and the dwelling (*awi*, in the Turkana language) is made of various huts with different functions and surrounded by the enclosure made of dry and very thorny acacia twigs. The huts are shaped as cupolas with an acacia timber structure covered by a herbaceous layer and leaves from doum palms or other plants.



Building techniques of dwellings-huts are used also for solid fences and gates, as well as to protect the young trees from goats and the sun.

A system which uses palm leaves is the so-called MAKUTI, a sort of 'shingle' made of leaves tied with wire to a stick and assembled with others on a wooden structure so as to form a cover which has an excellent thermal insulation performance and provides shelter from the rain. It is used for roofs of huts, arbors, etc., and a thriving market exists for them in the building of tourist resorts in Africa and warm countries in Asia.

Another system is called MARARA, which follows the weaving system used for making the walls of huts and which is usually used for building enclosures that can resist the strong local winds. It is made from the leaves of palms and other plants tied together with strings made from plants which then form sheaves approximately 1.5-2m high, assembled together with wire and tied to stakes firmly planted in the ground. There are no nails which with the wind would become detached from the wood.

We used both techniques. Makuti for the arbor for protecting the plants in the Nursery at the Nanyori Group area and for fencing the area of the Vetiveria plantation and Marara for all other fences.

The construction of the fences proceeded in stages. A first stage concerned the setting of the boundaries of the areas temporarily assigned to the project by the community (common land) with barbed wire or wire mesh, stakes and wooden gates, necessary for the actual availability of the land.

A second stage consisted in adding in a sort of 'sandwich' the dry vegetation to the elements already placed during the first stage, leaning against the stakes anchored and cemented to the ground. To the base of this fence were added rows of stones cemented together for preventing the intrusion of animals.

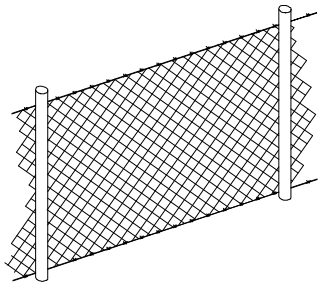
This system permitted obtaining a more solid structure and more resistant to the strong winds that hit the area of lake Turkana, as well as more compact, which helps keeping out the goats and offers protection to the vegetation from the dust and debris carried by the wind.

Fig. 1 Turkana settlement as a Kraal. (Photo: L. Vallerini).

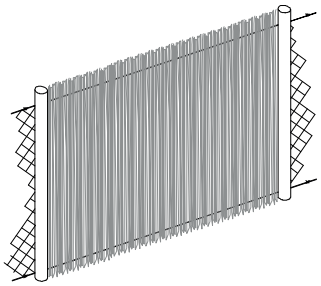
Fig. 2 Fencing for Nanyori area. (By: L. Vallerini).

Fig. 3 Final fencing for afforestation area. (By: L. Vallerini).

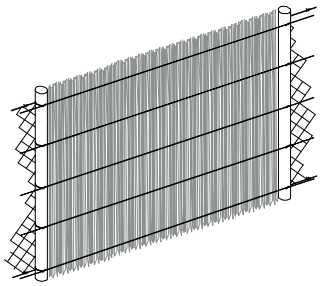
Fig. 4 Final fencinf details. (By: L. Vallerini).



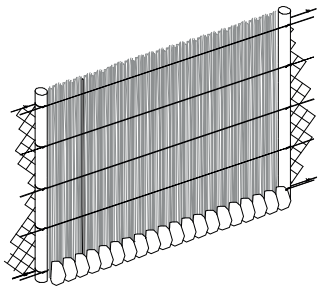
STEP 1 | Existing fence
(view from inside the nurssery)



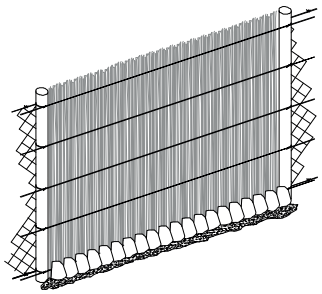
STEP 2 | Add Marara bords
(interwoven dry palm leaves)



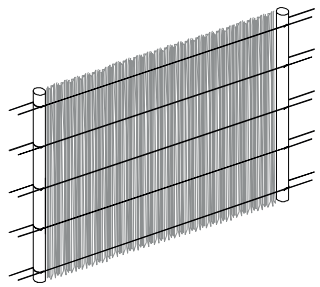
STEP 3 | Add iron wire (5 rows)
to secure Marara to the fence



STEP 4 | Position a kerb of stones (approx 15-20cm tall and 10-20cm wide) at the bottom of the fence

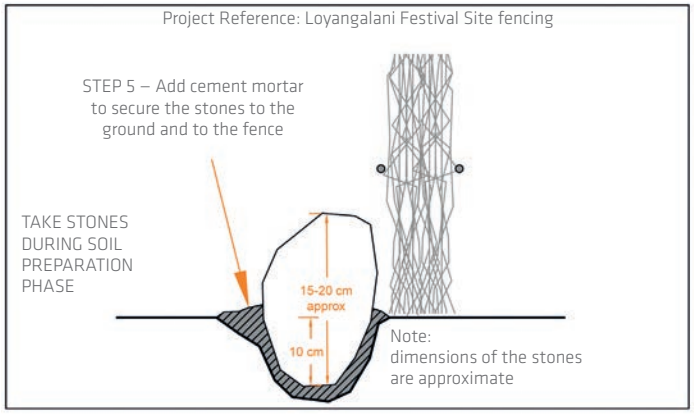


STEP 5 | Add cement mortar to secure the stones to the ground and to the fence



SCREEN FOR COMPOSTRE AREA

Project Reference:
Loyangalani Festival Site fencing + Palm Shade fencing



Endnotes

[1] UNESCO, International Traditional Knowledge Institute 2017, *TKWB - Traditional Knowledge World Bank*, available online at http://www.tkwb.org/w/index.php/Main_Page.

[2] "The difference in thermal inertia with the atmosphere creates colder surfaces which determine the condensation, the walls intercept wind and humidity, the spaces between the blocks and the porosity of the rock retain water, shade protects from evaporation, the boulders impede the dissolution of the soil and help in the formation of humus while maintaining the hydromorphic quality of the ground and function as thermal regulators and equilibrate humidity in arid situations" (Laureano, 2001).

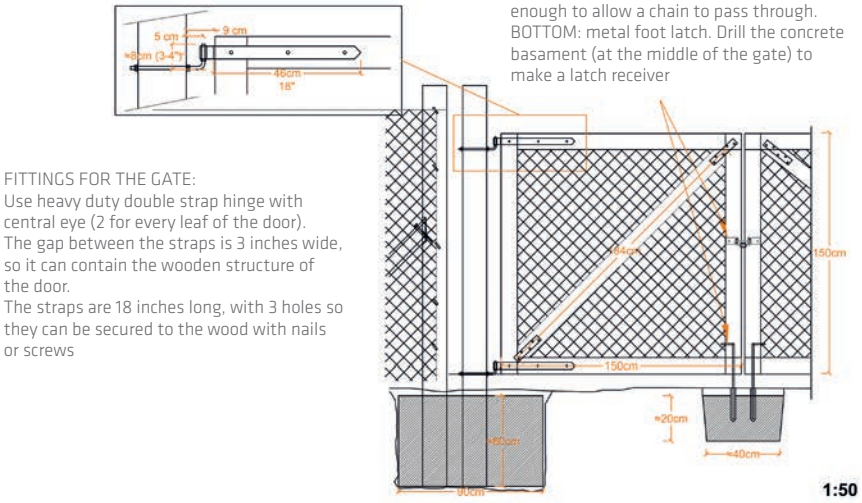
[3] Laureano P. 2001, *Atlante d'Acqua. Conoscenze tradizionali per la lotta alla desertificazione,* Bollati Boringhieri Ed., Torino, p. 325; Laureano P. 1998, *La piramide rovesciata,* Bollati Boringhieri Ed., Torino, p. 31.

[4] Once the dune has been formed it may be consolidated by planting shrubs and small trees such as *Tamarix gallica* which foster the creation of a micro-climate favourable to the development of crops, while simultaneously planting inside the area small groups of trees that provide shade and concentrate humidity.

[5] Kraal is an Afrikaans word which is also used in South African English derived from the Portuguese 'corral' (enclosure), which is precisely an enclosure for livestock inside an African village or settlement, surrounded by a palisade, a mud wall, or some other type of fence, in an approximately round shape. The same word is used for referring to a typology of African village made of huts placed around the said enclosure for livestock.

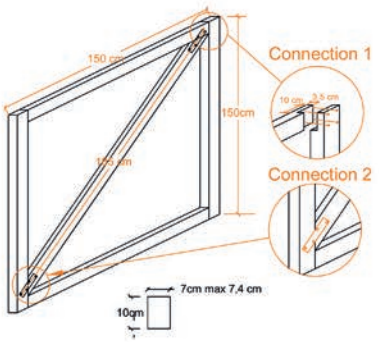
Fig. 5 Traditional building methods. (Photo: L. Vallerini).

Fig. 6 Entrance Gates — Construction Details



CLOSING SYSTEM
TOP: insert 2 eye bolts along the height of the vertical elements of the door, wide enough to allow a chain to pass through.
BOTTOM: metal foot latch. Drill the concrete basament (at the middle of the gate) to make a latch receiver

FITTINGS FOR THE GATE:
Use heavy duty double strap hinge with central eye (2 for every leaf of the door).
The gap between the straps is 3 inches wide, so it can contain the wooden structure of the door.
The straps are 18 inches long, with 3 holes so they can be secured to the wood with nails or screws



Vertical and horizontal elements of the door are rectangular timber profiles

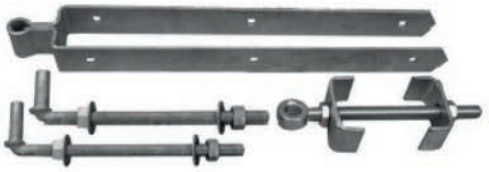
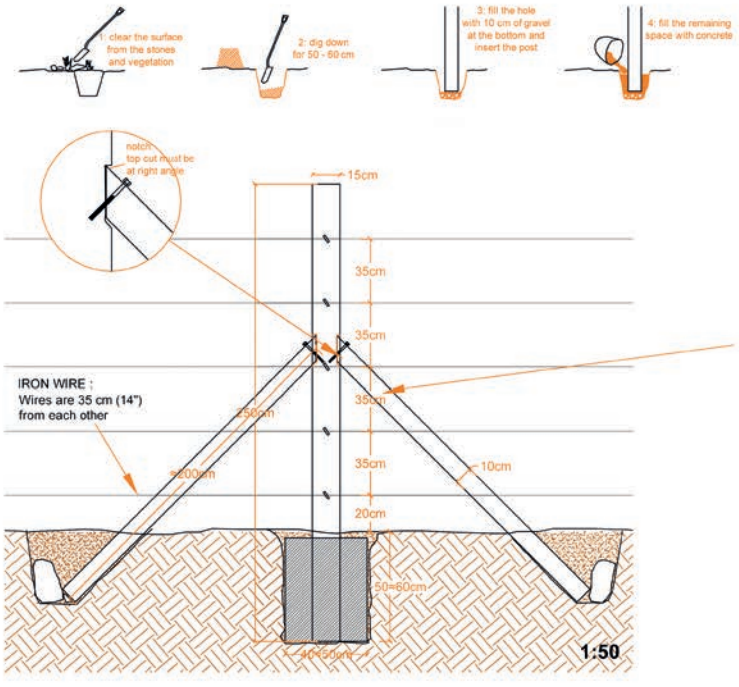


Fig. 7 A man making Makuti. (Photo: L. Vallerini).

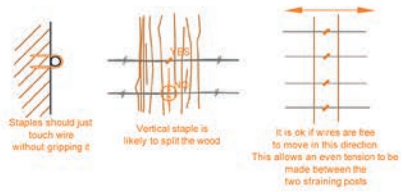
Fig. 8 Positioning of Posts and Struts — Nanyori Area Fencing and Compost Area Screen

CONCRETE PLINTH OF THE POSTS



STRUT: wooden elements (round posts of 10cm diameter and 200cm high) supporting the main posts of the fencing. Struts must be positioned at half of the height of the corner post, with a 45 degrees inclination, and must be planted in the ground

SECURING BARBED AND IRON WIRE:
Use staples to secure the wire. Don't leave a large gap between staple and wire. Staples must be positioned with an angle because if the staple is aligned vertically with both points entering the same grain, wood is likely to split



STRUT connection to the corner post: the head of the strut must be cut with a 45 degrees angle. Strut must be positioned in place (create a notch in the surface of the corner post) and bolted to the corner post

POSITIONING OF THE STRUTS

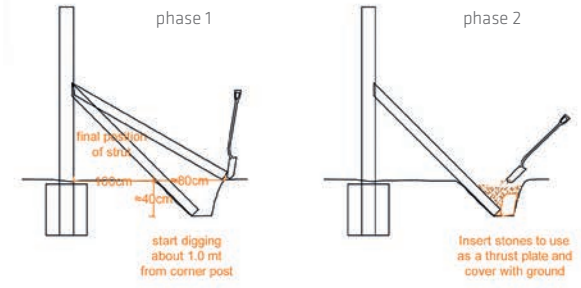


Fig.9 Makuti system. (Photo: L. Vallerini).
Fig. 10 Fencing construction with Marara. (Photo: L. Vallerini).
Fig. 11 Marara fences. (Photo: M. Folini).

Fig. 1 The logo of Nanyori Group CBO.
Fig. 2 The members of the Nanyori Group. (Photo: J. Nakhulo).

NANYORI GROUP CBO

Lorenzo Vallerini

An important role in carrying out interventions related to the project from the very early stages was played, and is played still today by the local *nonprofit* Community Based Organization – CBO, the 'Nanyori Group'.

The word '*nanyori*' in the local language means '*green belt*', because not long ago this area was covered in trees and greenery.

It is a group of volunteers, originally founded by Wings for Earth-WFE[1], who built the first nursery (different from the one currently active) and began the planting of numerous trees in the entire area of Loiyangalani (it has already planted or sold 1,500 small trees), thus contributing to the diffusion of techniques which have now become consolidated among the local population, and in fact providing an important initial thrust to this project.

The *Nanyori Environmental Conservation and Rehabilitation Youth Group,* which was created in 2006, consists of approximately 20-30 members coming from all the different ethnic groups in the community: the Turkana, Samburu, El Molo and Rendille. It has a well organised structure, with a president, a vice president, a secretary and a treasurer, and the members of the group contribute with a small annual fee to the life of the CBO, but the group manages to carry out its activities mostly thanks to the contributions from local entities, NGOs and some private donations. Its current headquarters are at the new M&C Centre built as a part of this project, and plants are already being distributed to the community from the new Nursery.

The group originated with a main objective, that is to combat esertification, using local plants and seeds, grown and reproduced specifically for being planted in the area of Loiyangalani in order to increase the vegetation mass in the oasis and to protect it from degradation, but also in order to provide economic and food resources to the local population. But not only, the group is committed as well to involve more and more people into a program for building a local *Green Belt*, to inform and educate regarding the dangers of desertification and the benefits of the conservation and rehabilitation of the oasis while also creating job opportunities and a sense of common purpose.

It was very fortunate for the purposes of this project to find a local organisation such as the Nanyori Group which shared the objectives of the project and even helped in identifying them with greater clarity, especially during the initial stages concerning studies and research, widely supported by the local knowledge transmitted to the project during all phases of development.

The role of this group will continue to be essential after the project is completed and handed over, and will carry out its positive and praiseworthy activities with outside help and support.

Endnotes

[1] The ONG *Des Ailes pour la Terre* or *Wings for Earth* (WFE) based in the Principality of Monaco initiated a program in 2006 called '*Nanyori Green Belt*' for the protection of the resources and the ecosystems and for socio-economic self-sufficiency in Loiyangalani, directly involving institutions, associations and launching actions to raise awareness in the local population, something that is key to any future activity. The Nursery, realized in order to grow the necessary plants for the new plantations also with alimentary purposes and/or sale of the products, was managed directly by the Nanyori Group founded by WFE.

Awareness and Management

Awareness and Information activities at the Nursery with the trainers of the Baraka College. (Photo: P. Magazzini).

Information and awareness

Planting training at Palmeraie area. (Photo: J. Nakhulo).

Fig. 1 Public info activities at Nursery by Baraka College trainers. (Photo: J. Nakhulo).

Fig. 2 Public info activities at Palm Shade on Vetiver uses by Plus Kenya. (Photo: L. Vallerini).

Lorenzo Vallerini

Information and awareness raising activities on the several issues concerning the project played a fundamental role in the process of empowerment of the local population. These were aimed at involving the inhabitants, who are the true end users of the entire intervention, in the undertaking and eventually the management of the project areas and their future expansion.

It must be borne in mind, as mentioned earlier, that the ethnic groups that live in the area are not farmers by tradition, they are either nomad shepherds or fishermen, or both, but not peasant farmers. Except for the El Molo, who have always lived on the shores of lake Turkana and live from fishing, the rest have become sedentary by necessity rather than choice.

The *CBO Nanyori Group* was the first local entity involved in the information and awareness raising activities, yet other stakeholders were informed or involved during various meetings organised in Loiyangalani, as well directly during some work stages and finally in the management of some parts of the project.

Among these it is worth mentioning the *Mosaretu Group*, the *Rhino Women Group* and the *Merissa Women group* (women play a very important role in the communities and are in fact more reliable and active), the Gurapao CBO, the *APEI CBO*, the *Loiyangalani Beach Management Unit* (BMU), the *Loiyangalani Fisheries Cooperative*, the *Environmental Management Committee* (EMC), the *Loiyangalani Water Users Association*, etc., as well as the *Loiyangalani Catholic Church,* the *African Inland Church* (A.I.C.), a protestant mission in Loiyangalani, the *Loiyangalani Mosque* (religious groups coexist peacefully and the religious representatives were very useful in disseminating and encouraging new behaviours), the Primary and Secondary Schools in Loiyangalani were also important in teaching new generations a direct relationship with the land and its products, and other entities who in future must surely be contacted, informed and involved with the purpose of extending as much as possible certain techniques

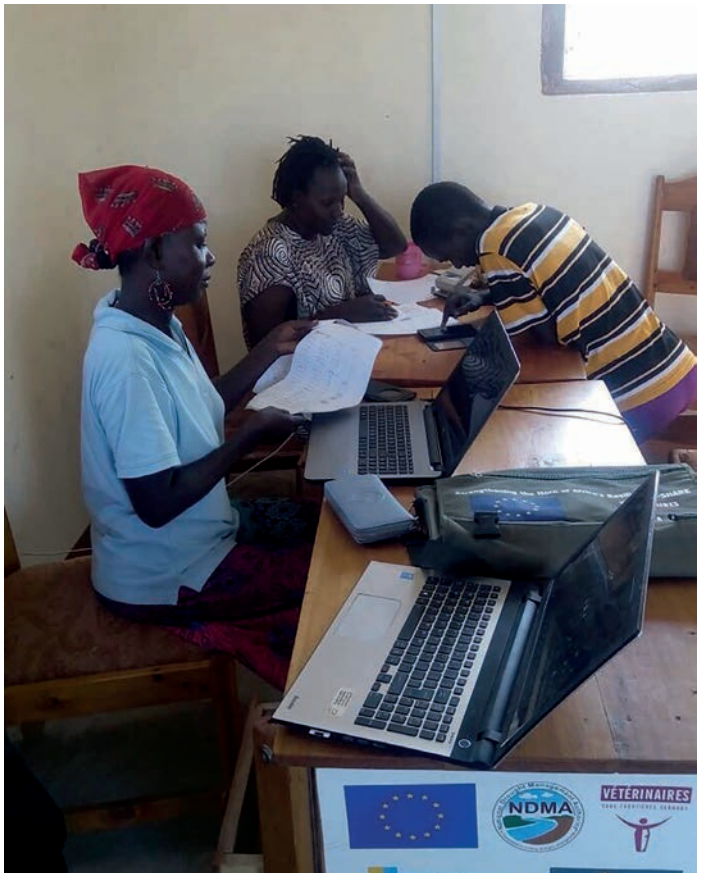


Fig. 3 M&C Centre activities on the computer use. (Photo: L. Vallerini).
Fig. 4 Activities in Palmeraie area. (Photo: J. Nakhulo).

and behaviors necessary for cultivating the land and ultimately for expanding the oasis.

The entire community should be involved in a process that surely concerns it as a whole, yet other possible resources which may in the future be invested in the area could generate conflicts. In order to avoid or mitigate these conflicts the advice and contribution of local experts will be necessary.

An important role was played as well by the local civil authorities, with a direct involvement by the *Marsabit County* and the *Laisamis Sub-County* in certain activities, as well as in the participation in meetings aimed at creating synergies for the implementation of the project together with other organisations and possible future partners, such as the *National Police Service*, *the Kenya Forest Services*, the *Kenya Agricultural and Livestock Research Organization* and the *Kenya Agricultural Research Institute*.

The aptness and availability of the various *stakeholders* was verified, entrusting however to a single entity the coordination, promotion and organisation of the various initiatives, namely our Water Right Foundation Loiyangalani Office, who at the same time coordinated all the stages of the realisation of the projects. This double role of the Staff of the WRF, carried out with the support of the Nanyori Group, was important because it permitted combining the realisation activities with those related to Information and Awareness, also through the direct involvement in some stages of realisation of people who participated in the Tutoring and Training courses.

The topics developed during the Information and Awareness activities were the following:

1. The knowledge of the oasis ecosystem, its vulnerabilities and potentials;
2. The problem of the scarcity of water and its management;
3. The combined management of water, soil and vegetation;
4. The knowledge of the soils in Loiyangalani, their protection and use;
5. The knowledge of the water system in Loiyangalani and the Turkana area;
6. The knowledge of the vegetation system in Loiyangalani;
7. The re-use of waste materials and manure (compost);

Figg. 5-6 Visit and training courses at the Baraka College in Nakuru. (Photos: J. Nakhulo).

8. Systems for protecting crops (fencing);
9. The knowledge of cultivation techniques;
10. Irrigation techniques;
11. The management of wells and springs;
12. The management of pastures and fodder;
13. The use of renewable energy for producing electricity (solar);
14. The promotion and qualitative and quantitative enhancement of local productions;
15. The reinforcement of commercial exchange with nearby urban centres.

The tools used were the following:

- The drafting of *Brochures* and *Information Sheets* concerning the project, its aims and the different elements that compose it;
- *Power Point* presentations concerning the various topics of the project;
- The production and distribution in Loiyangalani of T-shirts with the logo of the EU, the WRF and the Project itself;
- Public conferences organised in Nairobi; Marsabit and Loiyangalani, with the support of both the advisers of the *Turkana Scientific Research Group* and of other entities such as *Plus Kenya* on specific aspects;
- Public meetings in Loiyangalani, organised with the support of local entities and other associations or groups, with the purpose of generating interaction, involvement and exchanging information;
- A Vetiver Training activity carried out in Loiyangalani by *Plus Kenya* from Kitale during one week in 2016, aimed at training and educating to the practice of the cultivation and usage of Vetiveria for a group of approximately twenty people from the community belonging to the four main ethnic groups;
- A Tutoring and Training activity carried out in Loiyangalani by the *Baraka Agricultural College* from Nakuru for a duration of approximately sixty days throughout seven months in 2017 aimed at training and education, both theoretical and practical, concerning agricultural production activities for a group of approximately thirty people belonging to all four ethnic groups.

These last two activities were particularly important, since they were tested in the field, and produced the first concrete results which, more than any conference or lecture, contribute to change the attitude of the people and to convince them of the good path to follow, both as individuals and collectively.

The Vetiver Training activities carried out by Plus Kenya involved approximately fifteen labourers hired for the operations concerning the preparation of the soil and an additional twenty people both for practical and demonstrative activities and for fieldwork in related topics:

- planting-harvesting (theory and practice);
- vegetative multiplication and nursery management (theory and practice);
- use of leaves as animal feed for livestock (theory and practice);
- uses of the roots for production of other goods (theory)[1].

The activities of the Baraka College[2] were carried out mostly in Loiyangalani, but also at the headquarters of the College in Nakuru, alternating lectures and practical-demonstrative activities regarding the following topics:

Figg. 7-8 Activities at the Nursery on cultivation of new plants. (Photo: J. Nakhulo).

Subject	Objectives	Topics
Composting	To equip the community with skills and knowledge for composting to improve the soil fertility and structure for farming	Importance of compost manure Setting of the compost Methods of composting Materials required for composting Composting procedure Turning Storage of compost manure Utilization of the compost manure
Nursery management (Tree and vegetables)	To provide farmers with skills and knowledge in tree and vegetable propagation with the aim of increasing tree cover within their homesteads and farms	Nursery siting Lay out Nursery bed preparation Soil mixing Seed sowing /planting vegetative materials Potting and pricking out Managing potted stock Record keeping Gross margin analysis
Tree and fruit tree planting and management	To provide farmers with skills and knowledge in tree planting and propagation	Identification of suitable tree species Land preparation Hole preparation Tree planting technologies Preparation of the growing media Field management practices
Vegetable production	To improve the farmers capacities in vegetable production and hence improve nutrition and food security amongst the target community	Land preparation Appropriate technologies for dry areas Identification of Suitable varieties for dry areas Planting and management of vegetables Harvesting of vegetables Economics of vegetable production (Gross margin analysis)
Vetiver production	To improve the capacities of farmers in propagation and management of Vetiver grass, with the aim of increasing fodder for livestock which in turn will lead to improved nutrition (milk and meat) and food security	Land preparation Identification of suitable propagation materials Management of Vetiver grass Harvesting of Vetiver grass
Entrepreneurship	To nurture the entrepreneurial capacities of the target group to enable them carry out farming as a business	Business start up Business planning Start-up capital Costing and pricing Record keeping Financial management

All the activities of the Baraka College took place at the new premises of the M&C Centre with lectures and practical activities regarding the production of compost and the establishment of the new Nursery with an intense production of plantlets which were later used for the new plantations in the *Afforestation* area.

Also the planting of *Date Palms* in the *Palmeraie* and the expansion of Vetiveria in that same area, which had been decided the previous year, were practical activities carried out during the months in which the course took place.

The tutoring activities regarding composting were also particularly important because in nomadic cultures the concept of reuse is non-existent, since when the group moves it leaves behind anything that is not of use, including waste and rubbish; to change the attitude concerning these issues was fundamental for reversing the perspective on the fertility of the soil and generating awareness on the utility of recycling. The participants were first of all taught about bio-degradable materials, in particular about which to use and which not to, and about methods for the gathering and production of compost; in subsequent practical sessions materials were gathered and containers were prepared for their collection and the maturation of compost. During the gathering process various families in the community were involved, and they were motivated to do the same in their homes, or else to bring materials to the Compost Plant at the M&C Centre so as to obtain a final product for distributing to individual or collective cultivations.

The plant production at the Nursery is essential for the development of the project in its early stages, but especially later for being able to continue with the expansion of the oasis and for triggering initiatives for the marketing of products, so several sessions were devoted to this. The lectures regarded the knowledge of the plants and trees

Fig. 9 Working at Nursery under the arbor of the M&C Centre. (Photo: L. Vallerini).

in the area and of their features (adaptability to the arid and windy climate, to saline soils, the water from the springs, etc.), then the sessions moved on to practical training involving the various growing and propagation techniques, as well regarding transplanting to the chosen areas. Finally, specific instructions were provided regarding the management of the Nursery in order to ensure not only the quality of the plants produced and their possible sale, but also the transfer of these techniques to other members of the community. Other sessions were devoted to methods for the planting and use of the Vetiveria, with special attention to the production of products derived from the roots of the plant, in continuity with what had already been initiated in 2016 by Plus Kenya.

Last, but not least, the session devoted to the cultivation of vegetables for food purposes (cabbages and other collard greens, tomatoes, peppers, beans, melons, etc.) and of small trees which can provide fodder (Moringa, Lucerne Tree, etc.) with the aim of ensuring food security in Loiyangalani. In fact at present all vegetables consumed in this area are imported from relatively distant places, with the exception of a few very small vegetable gardens for self-consumption, and what is found in the market is not enough for satisfying the needs of the population. Participants to the course were also informed about plants and their nutritional properties, and about methods of cultivation and the creation of a vegetable garden. Additionally, experimental cultivations were carried out in the Nursery.

Finally, special attention was placed on the need to transmit the first notions of 'entrepreneurship', that is how to transform activities regarding the self-production of food into activities that produce an income, by selling the surplus of the agricultural production and their by-products, both in Loiyangalani and in the surrounding areas. Initiating a start-up agricultural company which carries out a 'social' production of food and other products derived from the Nursery, the Palmeraie and their vegetable patches, as well as from the plants of the Afforestation and Vetiver areas, could produce wealth to be distributed as income to the people who work in them.

Recently a woman in Loiyangalani, as a result of these initiatives, transformed her home vegetable patch into a small successful farm, thus providing income for her family "I'm optimistic of the future, I'm no longer idle and because demand for vegetables in Loiyangalani cannot go down, I will turn all this empty space in my homestead into a farm"[3].

After all, saving the oasis means saving the people in it, but also giving good opportunities to the people means safeguarding the oasis and its resources.

Endnotes

[1] Wegesa J. B., Plus Kenya 2016, *Report on Vetiveria zizanoides planting and management techniques training in Loiyangalani, Laisamis Sub-County of Marsabit County*, June 24th, Kitale.

[2] The two trainers of the Baraka Agricultural College have been Mr. Majanga A. and Ms Nasimiyu P.

[3] Nakulo J., WRF 2017, *'Mama mboga' in Loiyangalani!*, Report.

POPULATION. ETHNIC GROUPS IN LOIYANGALANI

Lorenzo Vallerini

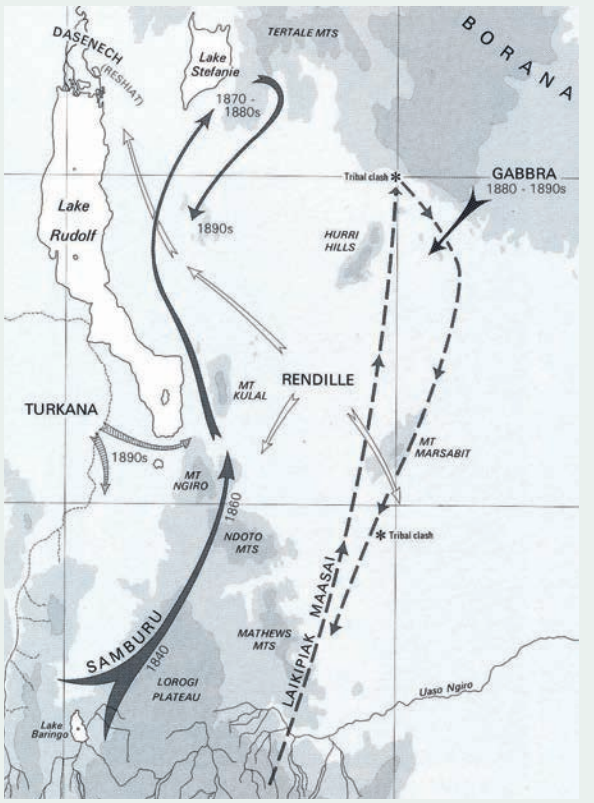


Fig. 1 Movement of the various ethnic groups during the 19th century, to the east of lake Turkana (Source: Brown Monty, Where Giants Trod – The saga of Kenya's Desert Lake, Quiller Press Ltd, London, 1989).

The village of Loiyangalani, which was founded in 1960, had 500 permanent residents in 1980, and by the 1999 census the population was approximately 1.000 inhabitants, yet today there are more than 5.000 people living either in the oasis or in the surrounding areas.

There have always been cases of violent cattle raiding in this area, to the point that it can be considered part of the local culture. This, together with inter-ethnic troubles, has increased when these different groups have found themselves sharing a single territory and the same limited resources. The situation, however, seems to have returned to normal.

The inhabitants of Loiyangalani mainly belong to four ethnic groups: Turkana, Samburu, Rendille and El Molo.

The Turkana are the most important and numerous Nilotic group[1] which moved to the west of Kenya from the region of Uganda, colonising first the west of lake Turkana and subsequently in the 19th century to the east, which brought about violent conflicts with other ethnic groups such as the Borana and Rendille.

The Turkana population is approximately 340.000. They speak a language which belongs to the oriental Nilotic languages, known as Turkana language (the local name for the language is *Ng'aturk(w)ana*). Tall, strong, very dark-skinned and rough in character, for a long time they constituted a formidable and aggressive group which expanded and defended their territory; their attacks in fact reached areas very distant from their settlements, deep into the territory of other ethnic groups, as far as the river Uaso Ngiro to the south and to the borders of Somalia and Ethiopia to the east.

The Turkana call themselves the *people of the grey ox*, in reference to the zebu, whose domestication played an important role in their history. Livestock is important for the economy of the Turkana, who in addition to the zebu keep goats, camels, donkeys and sheep. Other than for producing meat and milk, livestock is used by the Turkana as a commodity for bartering, or as dowry in marriages. The Turkana are polygamous, and the number of wives depends on the head of cattle the individual possesses. They are also well known for their woven baskets and the great number of necklaces worn by the women. The number of necklaces represents the wealth of the family, so sometimes they wear remarkable amounts.

Fishing, once considered taboo for a culture such as theirs, based on shepherding, has become widespread as a consequence of development programmes coordinated by the Kenyan government or European NGOs.

The Samburu are also a Nilotic people located in the district of Samburu to the south of lake Turkana. They probably came from the lands to the east of lake Baringo and settled more recently in the area to the south-west of lake Turkana and as far as mount Kulal. They have often had conflicts with the Turkana, whereas they have often united with the Rendille. They are a relatively numerous ethnic group in the area of Turkana.

They speak the Samburu language, which belongs to the Maa language family, like that of the Maasai, to whom they are related (approximately 95% of their languages are the same). Like the Maasai, they are semi-nomadic shepherds; they breed zebu, sheep, goats and camels; recently they have begun to grow corn, potatoes and sorghum. Unlike the Maasai, they also feed on wild game.

They name *Samburu* is of Maasai origin and comes from the word *samburr*, which indicates a leather bag that the Samburu always carry with them. The Samburu call themselves the Lokop (or Loikop), which could mean 'masters of the land' (from *lo*, which indicates possession, and *nkop*, land).

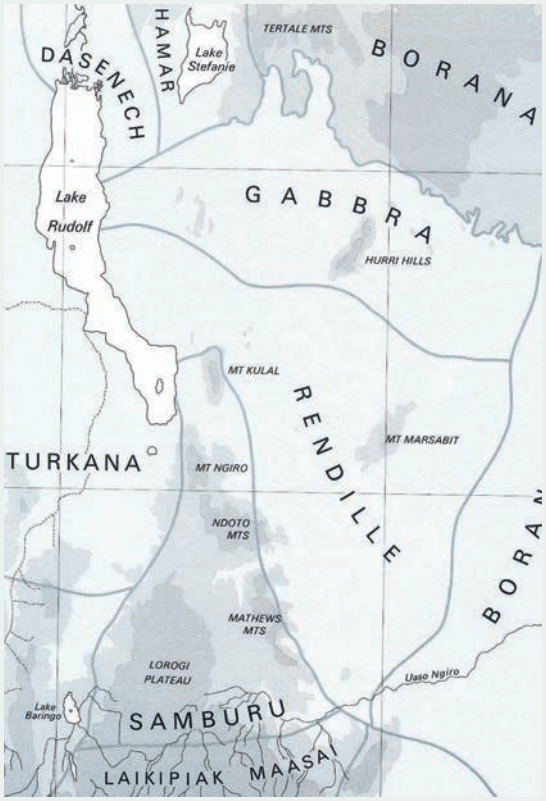


Fig. 2 Distribution of the various ethnic groups during the 19th century, to the east of lake Turkana (Source: Brown Monty, Where Giants Trod – The saga of Kenya's Desert Lake, Quiller Press Ltd, London, 1989).

It is not clear at what point in time the Samburu became distinct from the Maasai, but it was very probably during the colonial period. European travellers in the 19th century called the Samburu 'Burkineji' (*people of the white goats*), but it is not clear what their links to other groups in the area were at the time. Some Samburu are descendants from the Maasai of Laikipia, which were exterminated in the 19th century. Other are descendants from Rendille, Turkana or Borana. The social structure, divided in to age groups, seems to be an excellent example of gerontocracy, although contact with Western culture is undermining the importance of the elderly. Polygamy is permitted and widespread; a Samburu settlement (called *nkang, engang* or *manyatta*) can consist in a single family, that is a man and his wives; every wife builds her own house with materials found on-site, such as sticks, mud and cow dung. Larger settlements usually include two to three families; only ritual settlements (*lorora*) are more populated (20 or more families). Samburu villages are usually located on the top of hills. Women decorate their breasts with colourful necklaces made with beads sown unto leather (like the Maasai), but also from elephant tail hair; they wear bracelets and anklets made of copper, brass or aluminium. The *fundi*, or smiths, are a respected profession, usually practised by a whole family.

The Rendille, originally from Somalia, is a mostly nomadic ethnic group which has inhabited the vast area to the west of lake Turkana since the year 1000, when they emigrated from the south of Ethiopia.

Their area of influence includes the Chalbi Desert, through which they move with their camels, and the mountains of Marsabit and the territories to the west of that, as well as the west of lake Turkana itself. Their culture is in fact a mix of influences related to both the east and west of north Kenya, with similarities with the Samburu, with whom they have formed alliances and shared tribal traditions, although maintaining distinctly different languages and social organisations. Their alliance probably derived from the need to face the raids of the Turkana and Laikipiaks Maasai.

The Rendille are linked to their camels, who do not need green pastures like the Samburu do, and thus occupy the more arid and less fertile areas in the region.

The Rendille, although recent (and not so recent) unfavourable events have reduced their numbers, are found throughout the entire area to the west of the Turkana and provide their camels to the other ethnic groups and to adventurous tourists as transport for crossing difficult terrains.

This ethnic group is known for their peculiar and dazzling attire and decorations.

The case of the El Molo is different: a total ethnographic tragedy. Reduced to little more than 40 individuals, they are actually the original inhabitants of lake Turkana, and their villages are still located on the shores of the lake to the north of Loiyangalani, about a half-hour away by jeep (8Km) from the urban settlement. The El Molo, who call themselves the 'people of the lake', are a pacific, non aggressive group. The pirogues, the water, the fish and harpoons are their everyday tools for survival: fishing is their only activity.

Also their language is disappearing, forgotten by the El Molo themselves in favour of the Turkana language. For a few generations now parents have not been teaching their children the language, preferring Turkana, except for a few ritual words related to fishing. UNESCO has classified it as extinct. Few and defenceless, surrounded by aggressive tribes, with the passing of time they have intermarried with the larger ethnic groups, thus losing their culture; it is

Figg. 3-12 El Molo man and child; A man; Rendille Group; Samburu men; Samburu women and baby; Samburu women; Turkana female figure; Old woman; Turkana woman; Turkana traditional travelling with the wicker baskets on donkeys. (Photos: M. Cassitelli, M. Folini, L. Vallerini).

in fact an endangered group. When British explorers, following the traces of the Hungarian Count Samuel Teleki, who had 'discovered' the lake in 1888 and named it lake Rudolf, came across the El Molo they did not believe this ethnic group, a few scrawny shadows in a hostile desert and which they referred to as 'poor devils', had many chances of survival. In an article sent in 1913 to the Geographical Journal of London, Sir Jeoffrey Archer wrote: "The El Molo are a strange and pitiful remnant from the past. They descend from fishermen people". In 1934 the British colonial archives registered 75 individuals, pointing out that "their origin remains a mystery". The El Molo apparently stopped being nomads and became fishermen in order to stop having to fight their neighbouring tribes, seeking safety from a never-ending flight. Their only defence, to this day, is the lake. In case of danger they spread out on the ground nets covered in catfish bones: "The fish-bones wound the feet of the assailants, which gives us time to run to the canoes".

As it was at the beginning of the 20th century, when their huts were located in the bay of Alia, the El Molo always settle near an islet where they can take refuge in case of an attack.

The hardship of life on the lake, at the mercy of epidemics as well as of the whims of the sky and the water, with their unchanging diet (only fish) and the lack of fresh drinking water (they drink the water from the lake, which ruins their teeth and bones) have forced some of the most active members of the tribe to move to Loiyangalani.

"Eating only fish, drinking that water, it's no good. [...] The women walk many kilometres for gathering wood and palm leaves. They are often raped and the bums who do it know they risk no punishment. Here, however, we feel safe: those who are sick can go to the Catholic mission".

One of the few remaining traditions that unite this group is the hippopotamus hunt. "The hippopotamus is for the El Molo what the lion represents to the Maasai: in the past the life of the tribe revolved around them. A man with a knife can kill a crocodile, but for the hippopotamus twenty or thirty hunters are needed, and a lot of courage. When we organise a hunt it is always an occasion to celebrate and to commemorate our culture". Killing a hippopotamus means walking for three weeks, 200 kilometres along the shores of the lake, until reaching the Sibiloi reserve. "Only adults participate. The others will participate in the ceremonies. The older women will teach the younger ones how to cook the meet. The songs, the forgotten rituals will recover their meaning".

Endnotes

[1] The Nilotic peoples are those orginally established along the high valley of the Nile in what today is the south of Sudan. Around the 11th century many of these peoples travelled south along the Nile and settled in the lands where they live to this day in Kenya, Uganda and Tanzania. The Maasai, Karimjojong and Turkana are some of the most renowned Nilotic peoples.

RECOMMENDATIONS

People of Loiyang-lan after Sunday Mass. (Photo: L. Vallerini)

The Oasis as a paradigm of traditional knowledge, sustainable development and the combat against poverty

Falls at the uplands in Kenya. (Photo: L. Vallerini).

Lorenzo Vallerini

Back in 1966 the English economist Kenneth Boulding wrote an essay entitled *The economics of the coming spaceship Earth*[1] which made him far more famous than his long career as a university teacher, economist and peace activist ever did. In the said essay he criticised what he called the 'cowboy economy' and promoted the idea and the need to consider our planet as 'spaceship earth':

> The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past. For the sake of picturesqueness, I am tempted to call the open economy the 'cowboy economy', the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour, which is characteristic of open societies. The closed economy of the future might similarly be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy [solar energy].

Boulding's metaphor made a mark on the collective imagination and had a revolutionary effect, becoming a sort of emblem of the environmental movement, from the first Earth Day (April 22, 1970), and opened the way for reflections which a couple of years later, in 1972, led to the work and research that resulted in the report *The Limits to Growth*[2] by the Massachusetts Institute of Technology – MIT, which had been commissioned by the *Club of Rome*. This report, quite innovative at the time, which was based on objective research and scientifically proven data, triggered a complex and as yet unsolved debate between the supporters of development at all costs and those who advocate a balanced and sustainable vision of environmental, economic and social development.

The quote above is part of history now, although the words are so topical they seem to have been written only yesterday, yet it serves us as a starting point for establishing a parallel between the earth and the oasis. Planet Earth is an oasis floating in a hostile environment, space, while the oasis is an island of limited resources surrounded by a hostile environment, the desert.

In both the marcrosystem and the microsystem the same laws are in force, those of Ecology[3], in other words those that regulate the relationships of organisms with one another and with their physical surroundings. All organisms, humans included.

These laws permit the functioning of ecosystems which include both living, biological organisms, or biosystems, as well as non-living, or a-biotic systems which interact and influence each other and are necessary for the existence of life. When the network of interrelationships that exist between organisms and the environment is altered or broken, the life of the ecosystem itself is endangered: and this is true both for the biosphere, that is the Earth as a whole, and for a small ecosystem, such as a forest, a pond, or an oasis. Of course the more complex an ecosystem is the more it has a capacity to regenerate and self-adjust when facing strong external alterations, whereas the simpler it is (few components) the more fragile it also is. But in both cases, when facing strong external alterations their *steady-state* is modified, in other words the balance between what enters and exits the system[4] is altered, often with incalculable consequences.

This is the message of the Earth-Spaceship metaphor, that the size of our 'home' is limited, and so are our natural resources (air, water, soil, etc.), both renewable and non-renewable (fossil and mineral fuels, etc.) and that their transformation into 'goods' ultimately reduces them to garbage (in some cases indestructible) which then alter the network of interrelationships that is at the foundation of life, including that of the mammal known as man. Furthermore, the symbiotic processes between living and non-living organisms can be altered, turning into unexpected forms and modes which produce very troublesome feedbacks[5], from the environmental as well as the economic and social points of view: a proven example is global warming, regardless of more or less valid assertions in defence of a few big interests and of the status quo.

And these interrelationships are not limited to certain areas or scales but, given the complexity of ecosystemic relationships (an in-depth definition and explanation of which is beyond the scope of this text), extend to scales and geographical areas that are apparently not connected to alterations produced in other places.

A striking case comes from Antarctica, where a 200 km crack (lake Turkana is approximately 250 km long) generated by the warming of the ocean produced a gigantic iceberg that separated from segment C of the Larsen Ice Shelf on July 12, 2017. Known as A68, it has an area of almost 6,000 km^2 (the area of lake Turkana is approximately 6,500 km^2), is 350 metres high and is already approximately 2.8 kilometres away from the ice shelf. Its contribution to rising sea water levels will not be insignificant[6].

This is the classic 'butterfly effect', that is the concept that everything is interconnected, implying that the simple movement of the air molecules generated by the flapping of the wings of the insect can cause a chain reaction of movements of other molecules to the point of triggering a hurricane, perhaps thousands of kilometres away.

The fact that everything is interconnected is now obvious to many, since

> it is increasingly evident today that the crucial issues of our age – energy, the environment, climate change, poverty, violence and war – cannot be understood separately. They are systemic problems, that is interconnected and interdependent. The vicious circle of demographic pressure and poverty brings about a decrease in resources, an impoverishment which is exacerbated by climate change ... The dilemma at the basis of these problems seems to be the illusion that unlimited growth is possible in a limited planet[7].

The circular nature of the biological systems that regulate life on our planet clashes with the idea of a 'linear', utilitarian economic growth, which is based on waste and does not take seriously into consideration the possibility of the reproduction of resources, but rather sees everything as waste to be discarded at the end of the production and consumption processes. The fundamental elements of the biosphere, that is water, air and soil, are considered as a free gift which is always readily available, since they are at least partially renewable, yet their natural cycles are increasingly at stake and are facing a situation of crisis as a consequence of current usage and consumption trends, which result in feedbacks whose consequences, and the speed with which they will affect our lives, are not yet fully known.

If these considerations are valid for our Earth, they are also valid, according to the principles of Ecology, for all the ecosystems that form the system Earth, from the larger, more complex and natural systems, such as the oceans, the prairies, the forests, etc., to the smaller, simpler and perhaps man-influenced systems, such as, for example, an oasis.

An oasis, in fact, "is a human settlement which in an arid geographical context uses the available resources for generating an amplification of positive effects and creating a self-sustainable haven for life in a fertile environment which contrasts with its unfavourable surroundings"[8] and in which, although the only available resources are used, in other words water and the favourable environment created by it, soil included, these resources are supplemented with activities such as the cultivation of trees, plants and other agricultural products, as well as with structures that provide protection from the extreme conditions and raw earth buildings in an artificial balance between the available resources and their use, between nature and mankind, ensuring for the local inhabitants an environment and living conditions that are often quite favourable.

It is no coincidence that oases for centuries were 'harbours', or artificial 'stepping stones'[9], for caravans, that is both for men and animals moving from one area to another through the large desert expanses, and their presence, or absence, could represent the difference between life and death, or between having a home or having to move on in search of other places in order to survive.

The oasis as a human settlement is in fact quite the opposite of many other human settlements, such as our cities which dissipate resources and energy, it is in balance with itself, it regenerates the ecosystem it has developed, it recycles and re-uses the available resources and limits to the maximum the outputs, that is water dispersion due to direct sunlight, while maintaining a balance of the inputs through an efficient use of the water available. It is in fact a small steady-state ecosystem; an example of conservation and qualitative growth, both in environmental and in social terms.

Yet behind this small miracle lies also the use of ancient technologies and know-how which is also innovative when compared to the 'invasive' nature of much – not all, of course! – modern technology, which permits an interconnected operativeness between all activities, social needs and available resources. And this does not hinder

the agro-forestry production of the oasis, on the contrary it has increased its potential in the past, and to some extent continues to increase it today. In order to obtain a variety of produce, such as dates, figs, olives, peaches, apricots, etc., cultivation is carried out at different strata, the first and most important of which is that of the date palms, which are plants that grow very tall and provide the necessary shade for fruit trees, which are lower. These in turn provide an adequate environment for the growing of vegetables and possibly, when conditions allow it, of cereals.

"Oases are not spontaneous occurrences, but rather the result of the actions of man [...] they are the consequence of the application of techniques that are adequate for the environment in question that have been carried down from generation to generation, the result of ingenuity and knowledge"[10], such as the cultivation of the date palm, hydraulic techniques for the collection, storage and distribution of water through 'drainage tunnels', systems for gathering and collecting nocturnal humidity (stone mounds, half-moon mounds and dry stone walls or terraces), for collecting rainwater from the roofs of dwellings or underground (cisterns, hypogean water architectural structures, underground condensation chambers), as well as systems for protection from the desert and the winds using artificial dunes and stone walls which also help protect fertile soils, and methods for recycling organic waste.

The application of 'traditional knowledge' is now an integral part of international policies (UNCCD - United Nations Convention to Combat Desertification[11]), but also of many cooperation organisations, as well as of companies and enterprises which operate throughout the planet, and not only in developing countries. Yet what emerges from the most recent experiences is the adaptation or re-use of traditional techniques with the support of more evolved 'appropriate' technologies, in other words the combination with different and innovative techniques (for example renewable energy, fertilisers derived from recycling with the use of dual aqueducts, water from the atmosphere through condensers or aerial wells, new irrigation systems and crop weaving, etc.).

To increase the use of traditional knowledge does not imply sacrificing innovation. On the contrary, innovation enhances competitiveness, efficiency and productivity – the low levels of which are often criticised in traditional technologies –, although in fact the process involved is less immediate and is more labour intense. This is not a bad thing, however, especially in countries with increasing unemployment levels, yet the most important contribution is long term, since it ensures a greater stability due to the fact that the basic resources are not altered but rather put to good use. This is exactly the opposite of techniques that are developed based upon criteria which only consider specific immediate profits and which consequently bring about the plunder of the available resources and social impoverishment (dams, large canals, industrial crops, chemical fertilisers, etc.).

The 'oasis' system, with its complex ecosystem composed of human settlement and cultivated landscape, including palm groves, crops and systems for water collection and management, in which "a virtuous interaction of factors is created capable of triggering positive dynamic trends aimed at opposing the harsh and hostile context [of the desert]"[12], thus seems to be the reference model also for other parts of the world, in order to harbour living conditions which today, for all the reasons mentioned above, seem to be in an unstable state of equilibrium.

There was an inkling of this already fifty years ago when in 1969 U Thant, Secretary General of the United Nations, said

> I do not want to sound too catastrophic, but from the information available to me ... the countries belonging to the UN have barely ten years for putting aside their conflicts and commit to a global programme for curbing the arms race, rehabilitate the environment and control demographic growth, directing their efforts toward the issue of development. Otherwise it is to be feared that the problems mentioned will have increased, within a decade, to such an extent that they will be beyond our capacity to control them.[13]

Nations and men had been warned, and since then, at least in the field of knowledge and initiatives many steps have been taken and although only a small part of the world population seems to be committed with the necessary energy in the search for solutions, the understanding of the issues, the awareness of the limited nature of our environment and the development of different forms of growth, have increased enormously. This, however, does not seem to be enough for facing increased demographic growth, production and financial 'flows' lacking any ethical values and the 'bad' type of growth which have characterised the first years of this new century.

Fig. 1 The Sumerian clay tablets of the second millennium B.C. from the ancient city of Nippur (Source: http://bit.ly/2n151df).

> Since I wrote those pages – [2007 The world without us] world population has increased almost by a billion people, reaching today's 7.5 billion. It is an enormous pressure which they planet cannot withstand. If policies are applied [...] which continue to be based of fossil fuels we will never reach 10 billion. The world will come to an end before that.[15]

Weisman's apocalyptic considerations were well received by the public, yet did not find much success among the political class since, as David Attenbourgh reminds us,

> What politician would decide to undertake an initiative that is extremely expensive and does not produce visible benefits, at least not before the next elections, or the following ones? Long term problems require a farseeing and altruistic perspective that politics does not allow to cultivate.[16]

Yet the 'Renaissance' of the environment is within reach, all we need to do is to dig into our past as an agricultural society which for over ten thousand years, from the moment of the advent of agriculture, and consequently of our civilisation, has seen the increase in agricultural production and the defence of the available resources as two sides of the same coin.

The clay tablets, datable to the second millennium B.C., which were found in Iraq at the site of the ancient Sumerian city of Nippur by an American expedition undertaken in 1949-50 by the Oriental Institute of the University of Chicago and the University Museum of Pennsylvania, teach us how to behave in order to ensure the reproduction of the resources necessary for the maintenance of life. The laborious interpretation provided by archaeologists of the cuneiform writings consists of a series of teachings offered by the farmer Ninurta to his son instructing him on the work to carry out on specific days of the year. Based upon eight previously discovered clay tablets a document was reconstructed, 108 lines long, which in a way is the first Farmer's Almanac:

> When you are about to take hold of your field (for cultivation), keep a sharp eye on the opening of the dikes, ditches, and mounds (so that) when you flood the field the water will not rise too high in it. When you have emptied it of water, watch the field's water-soaked ground that it stay virile ground for you. Let shod oxen (that is, oxen whose hooves are protected in one way or another) trample it for you; (and) after having its weeds ripped out (by them) (and) the field made level ground, dress it evenly with narrow axes weighing (no more than) two-thirds of a pound each. (Following which) let the pickaxe wielder eradicate the ox hooves for you (and) smooth them out; have all crevices worked over with a drag, and have him go with the pickaxe all around the four edges of the field (lines 1-12).[17]

It seems like the handbook for the millions of 'micro-producers' of food that, having originated from grass-roots levels, are currently active throughout the world, both in industrialised and developing countries. These micro-producers are growing through small-scale trade and widespread market networks, which are the antithesis of the monocultural practices of multinational corporations – wasters of energy and large-scale producers of CO2 – and of large distribution systems, gradually incorporating unusual yet profitable methods of commercial integration and using agricultural techniques derived from biiodynamics, organic agriculture, agroecology, and so on, combining crops, livestock farming, agriculture and forestry techniques that increase biodiversity instead of decreasing it[18].

The Oasis paradigm is expanding, perhaps too slowly compared to the speed with which the global economy and climatic-environmental change are moving, yet it is a good model to follow that works, as it has for those who live in arid and semi-arid regions throughout the world and who have learned the hard and difficult lessons of the desert, by re-establishing the symbiotic alliance between man and his surrounding environment, and which has ensured the survival of the oasis, of their homes and resources in a perspective that goes well beyond a single generation.

The Oasis paradigm teaches us how to understand, use and preserve our resources and how to live – sufficiently! – happy lives.

Endnotes

[1] Boulding, K. E., 1966, *The economics of the coming Spaceship Earth*, in H. Jarrett (editor), *Environmental quality in a growing economy*, Baltimore, Johns Hopkins University Press, pp. 3-14.

[2] Meadows D. H., Meadows D. L., Randers J., Behrens III W. W. 1972, *I Limiti dello Sviluppo,* Arnoldo Mondadori Editore, Milano. The first update of the Report was published in 1992 with the title *Beyond the Limits*, in which it was affirmed that the limits of the 'load-bearing capacity' of the planet had been reached. A second update, with the title *Limits to Growth: The 30-Year Update* was published on June 1st, 2004 by the Chelsea Green Publishing Company. In this version the Report was updated and integrated, shifting the focus from the exhaustion of resources to the degradation of the environment.

[3] "The term Ecology, which has since been widely adopted by the common language was proposed in 1866 by the German biologist Ernst Haeckel in his book *Generelle Morphologie der Organismen* [...]. Ecology is the knowledge of the economy of nature, the investigation of all the relationships of a living organism with its environment, both inorganic and organic [...], it is the study of all these complex interactions, considered by Darwin as the conditions of the struggle for survival" (Aguesse, 1972).

[4] "Some ecosystems exist in a *steady state,* or *homeostasis.* In steady-state systems, the amount of input and the amount of output are equal. In other words, any matter entering the system is equivalent to the matter exiting the system. An *ecosystem* includes living organisms and the environment that they inhabit and depend on for resources. [...] Most systems continually shift inputs and outputs to maintain a steady state" (Spooner, 2017), available at http://www.dummies.com/education/science/environmental-science/what-is-a-steady-state-ecosystem/.

[5] "The adjustments that a system makes as inputs enter or outputs exit are called *feedbacks.* [...] *Negative feedbacks:* [...] slow down or suppress changes, sometimes helping the system return to a steady state. *Positive feedbacks:* [...] lead to increased change, sending the system further away from a steady state. Feedbacks often set off a chain of changes, [...] population growth can create a positive feedback loop. When more births occur, the next generation has more people to have more babies[...], and so on. Thus, positive feedback loops can lead to runaway effects [...] sending a system far from its steady state. In the context of systems, the terms *positive* and *negative* don't mean good and bad. In fact, positive feedbacks are often more dangerous than negative feedbacks because they move a system further from stability [...]. (Spooner,2017), available at http://www.dummies.com/education/science/environmental-science/what-is-a-steady-state-ecosystem/.

[6] Dusi E. 2017, *Quel gigante di ghiaccio che si stacca dall'Antartide,* «La Repubblica», June, 4th*;* Marini M. 2017, *Antartide, il gigantesco iceberg si sta già rompendo,* «La Repubblica», July, 20th.

[7] Capra F. 2016, *La crescita illimitata è economia dello spreco*, «La Repubblica», November, 29th.

[8] Laureano P. 1988, *Sahara Giardino Sconosciuto*, Giunti, Firenze.

[9] *Stepping stones*, in the system of 'ecological networks', are habitats developed on small areas which due to their strategic position or their composition, represent important sites for the rest of species in transit through a territory that is not adequate for their survival. They are small *habitats* in which species can find shelter and food on a temporary basis (for example a system of small ponds within a wide agricultural area along wetland bird migration routes).

[10] Laureano P. 2000, *Atlante d'acqua, conoscenze tradizionali per combattere la desertificazione*, Bollati Boringhieri, Torino.

[11] 3rd Scientific Conference UNCCD *Combating drought, land degradation and desertification for poverty reduction and sustainable development*, 9th-12th March 2015, Cancún, Mexico.

[12] Laureano P. 1995, *La piramide rovesciata, il modello dell'oasi per il pianeta terra*, Bollati Boringhieri, Torino

[13] Meadows D. H., Meadows D. L, Randers J., Behrens III W.W.,1972, *I Limiti dello Sviluppo,* op.cit.

[14] Weisman A. 2007, *The World Without Us,* Thomas Dunne Books/St. Martin's Press, New York; Weisman A. 2008, *Il mondo senza di noi*, Einaudi, Torino.

[15] D'Alessandro J. 2017, *Attenti, la natura si vendica siamo troppi sulla Terra*, «La Repubblica», March, 3rd.

[16] Kahya D. 2017, *Vi racconto il pianeta*, «La Repubblica», September, 30th.

[17] Kramer S. N. 1963, *The Sumerians: Their History, Culture, and Character*, The University of Chicago Press, Ltd., London. Appendix L is a translation of the *Farmer's Almanac*, prepared in collaboration with Thorkild Jacobsen, Benno Landsberger, and Michel Civil.

[18] An American research institute, the Rodale Institute, which has been supporting organic cultivation systems through study and research, has proven that the organic practices used in farms over the past thirty years have increaed the level or carbon retention in the soil in 30%, thus significantly contributing to the reduction of CO2 in the atmosphere, while also enhancing the fertility of the soil. Industrial productions which use large quantities of chemical fertilisers obtain diametrically opposed results. Rodale Institute, 2011, *The farming systems trials-Celebrating 30 years*, Pennsylvania, available at https://rodaleinstitute.org.

Lake Turkana from the rivers of the Sibiloi National Park. (Photo: L. Vallerini).

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Brief Biographical Statements and activities of the Non-profit Organizations -NPO

PAOLO ALTEMURA is a chemist who is an expert in research concerning micropollutants. Since 1990 he holds a managerial position at the Tuscan Regional Agency for Environmental Protection (ARPAT). He obtained a PhD in chemistry in 1989 and has taught at the University of Pisa as well as in training and master courses both in Italy and in Europe. He is the author of dozens of publications in international scientific magazines on themes of analytical chemistry.

GIOVANNI CAPONI is a freelance surveyor who since 1980 has been involved mostly with aerophotogrammetry and topographic surveys. He has participated in the drafting of important maps and in surveys concerning the morphology of the terrain throughout the entire national territory, as well as in high-precision landslide controls and road layouts.

GIANCARLO CECCANTI is a freelance geologist who since 1982 has been mostly involved with hydrogeology and extractive activities. In order to devote himself more specifically to water research in developing countries, in 2008 he founded, together with other colleagues, Acquifera, a small technical organisation which operates in the field of international cooperation.

MARCO FOLINI is a freelance geologist who since 1986 has been mainly involved with geotechnical engineering and applied geology, as well as with hydrogeology and extractive activities; he has undertaken numerous projects both in Italy and abroad, mostly regarding the search for water and water collection and distribution in developing countries. Since 2008 he has been an active member of Acquifera Onlus, through which works for international cooperation projects. He operates in interventions involving international cooperation.

PIERO MAGAZZINI graduated in Agricultural Science at the University of Florence.He has collaborated in several research projects and his main activities have involved consultancy as a soil scientist, soil surveyor and GIS expert in many national and international projects (Africa, Iraq, Serbia, etc.). He has also been involved as a teacher in many master courses in Italy and abroad and is the author of 31 scientific and professional publications with soil maps or suitability maps for crops.

MARCO MAZZONI is a chemist who held a managerial position at ARPAT, first at the Provincial Department in Prato and later at the Central Technical Directorate. During his professional career he has worked as a consultant for ISPRA, ISS and the Ministry of the Environment, where he is currently a member of the AIA-IPPC Commission, a body which is in charge of issuing Comprehensive Environmental Licenses to companies at a national level.

SAVERIO MECCA Architect, Full Professor of Building Production, Dean of Department of Architecture at University of Florence, Director of the research unity INN-LINKS (Research Center on Innovation and Local and Indigenous Knowledge Systems), director of the scientific journal Ploes Heritage for the future and member of ICOMOS-ISCEAH.

LORENZO NOFRONI is PhD in Landscape Architecture (ICAR 15), he attained the title at La Sapienza University of Rome, PhD curriculum in design and management of environment and landscape, Cycle XXIX, academic year 2016-17. Graduated in architecture, at the University of Florence, academic year 2009-10, he attained the title of Ph Master in landscape planning, at the University of Florence, academic year 2012-13. He is a freelance architect, since 2011 collaborates with ArchLand Studio.

UGO WOLF was Associate Professor (AP) in Soil Science at the Department of Soil Science and Plant Nutrition (University of Florence) from 1978 to 2011. His main fields of interest, also concerning his research activities, are soil science, soil survey, mapping and classification, soil evaluation, soil and landscaping. His soil survey activities have been carried out both in Italy and abroad (Africa, south-east Asia). He is the author of 35 articles published in Italian and international reviews.

ACQUIFERA ONLUS, founded in 2008, is a non-profit organisation of Italian geologists involved in projects in places where there are problems related to the scarcity of water or contaminated sources, with the aim of making water available in developing countries through direct interventions – the drilling of wells, water collection and adduction – using the most technically and scientifically advanced methods of research, planning and design for improving the living conditions of the communities involved.

WATER RIGHT FOUNDATION-WRF is a not-for-profit organization based in Italy with a mission "to foster cooperation interventions, research training and education activities on the themes of universal access-to-water right and sustainable use of water resources" in a wider framework for the conservation and compatible use of natural resources. Since 2005, the year in which WRF was founded, Publiacqua S.p.A., the company that manages the integrated water service in the metropolitan area of Florence in Tuscany, Italy, donates one cent of a Euro per cubic meter of water consumed by users to a Fund named '*L'Acqua è di tutti*' (Water belongs to everybody) in order to realize interventions in those countries where water is insufficient or badly managed. WRF works worldwide to promote rights of access to water, through both research and technology, as well as through education and training. It promotes development cooperation projects, information and awareness activities on access-to-water right and sustainable management of resources, environmental education activities in schools, research projects with the University of Florence and training workshops for the maintenance of infrastructures. WRF is the promoter of the project for the OASIS ECOSYSTEM OF LOIYANGALANI and is engaged in many aspects, such as management of the project, managing staff, building infrastructure, planting trees and providing scientific and technical expertise. Moreover, it has co-financed the project for about 30% of the total budget.

Italian Summary

El Molo village along the Lake Turkana. (Photo: L. Vallerini).

LE ORIGINI DELLA TERRA E L'UOMO

Oasis Ecosystem | Progetto di lotta alla desertificazione

Loiyangalani, Lago Turkana, Contea di Marsabit, Kenya, 2015-2018

Il Lago Turkana (in passato chiamato Lago Rodolfo, in onore del principe austro-ungarico Rodolfo d'Asburgo-Lorena dagli esploratori Samuel Teleki e Ludwig von Höhnel, che furono i primi europei a raggiungerne le sponde nel 1888) è il più grande lago permanente in luogo desertico del mondo. Situato nella Rift Valley, nel nord-ovest del Kenya, lungo quasi 300 km. ha una superficie di 6.405 km², quasi completamente all'interno dei confini del Kenya; solo la parte settentrionale si trova in Etiopia, in corrispondenza del delta del fiume Omo, suo principale immissario.

Tutta la regione ed il bacino del Lago Turkana sono caratterizzati da terre aride e semiaride sul 100% del loro territorio. Il processo di desertificazione in atto sta portando ad una graduale anche se irreversibile riduzione della capacità del suolo di produrre risorse e servizi dalle quali dipendono le popolazioni che vivono lungo le sponde del lago e nell'intera regione. In questo luogo, più di ogni altro, cibo, acqua, territorio rappresentano gli elementi su cui si fonda e da cui dipende la vita di queste genti. Conservare e migliorare lo stato dell'ambiente nel quale vivono rappresenta un fattore cruciale nella sopravvivenza futura di queste etnie, lontane parenti dei primi ominidi che calcarono questi luoghi. E non si pone solo il problema della loro sopravvivenza a fronte dell'avanzamento dei processi di desertificazione, ma, in assenza di interventi strutturali, anche quello di una loro forzata emigrazione verso altre aree della regione e/o verso altre aree geografiche, per non parlare della loro perdita di identità culturale e dell'abbandono di vasti ambienti al progressivo processo di degradazione.

Il progetto *Oasis Ecosystem* mira a realizzare un prototipo di 'rivegetazione' finalizzato ad ampliare l'ecosistema dell'Oasi di Loiyangalani, ad aumentare la produttività alimentare ed a fornire nuove aree di 'pascolo' per gli animali domestici (capre e asini) che sono una delle principali cause/effetti di degradazione del suolo. Per realizzare tutto ciò è indispensabile anche incrementare le risorse idriche disponibili, sia per finalità irrigue che idropotabili. Nonostante, infatti, nell'Oasi vi sia una importante presenza di acqua da sorgenti termali provenienti dal Monte Kulal, anche la zona dell'Oasi di Loyangalani è di per sé arida e con suoli sterili, molto calda e percorsa da venti forti, con una grande massa di acqua, quella del Lago Turkana, apparentemente disponibile, ma, causa la forte alcalinità delle sue acque, non utilizzabile per scopi potabili né per finalità irrigue.

Il progetto *Oasis Ecosystem* si caratterizza per la metodologia di lavoro applicata. Si parte da una ricerca applicata 'sul campo' sviluppata su basi scientifiche; si utilizzano, per quanto possibile, le conoscenze tradizionali locali, ma anche tecnologie innovative 'semplici' e 'rinnovabili' per risolvere i problemi e garantire autonomia alle popolazioni per la gestione futura dell'ecosistema. Le attività di ricerca e monitoraggio dei risultati in un ambiente così estremo rappresentano un 'laboratorio a cielo aperto' per sperimentare soluzioni applicabili in altri contesti similari dell'intera regione, ma anche nelle aree mediterranee dove la desertificazione è un fenomeno in rapida espansione.

Il progetto di conservazione e ricostruzione dell'Oasi in una visione olistica delle problematiche connesse alla progressiva rarefazione del sistema Oasi, mira a:

- Conservare e ricostruire le risorse dell'ecosistema come fattore-chiave di lotta alla desertificazione;
- Implementare le risorse idriche disponibili sia per finalità irrigue che idropotabili;
- Realizzare un prototipo di 'rivegetazione' finalizzato ad ampliare l'ecosistema Oasi, a aumentare la produttività alimentare per le popolazioni locali e a fornire nuove aree di 'pascolo' per gli animali domestici (capre e asini) che sono una delle principali cause/effetti di incremento della perdita di suolo;
- Coinvolgere ed informare-istruire le popolazioni locali nella realizzazione e nella gestione delle risorse idriche, delle aree-prototipo e di altre aree rivegetate-produttive e migliorare le condizioni socio-economiche delle comunità locali.

Il progetto 'Conservation and reconstruction of the Oasis Ecosystem of Loiyangalani' è stato oggetto di una Ricerca e di uno *Studio di Fattibilità* redatti tra il 2008 ed il 2010 e finanziati dalla Water Right Foundation, dall'Università degli Studi di Firenze e da Acquifera Onlus con il supporto del *Turkana Scientific Research Group*[1].

Il progetto finale e la realizzazione sono stati finanziati dalla *European Commission* nel 2014 per un importo complessivo di € 503.344,00 all'interno del progetto '*Kenya: Community Action for Improved Drought Resilient*' in partnership con la ONG '*Veterinarians without Borders, Germany*' (VSF-G) (soggetto capofila del partenariato) e la ONG '*Water Right Foundation*' (WRF-Italy) che ha contribuito con un cofinanziamento pari ad oltre il 30% dell'importo del progetto. Le attività di progettazione esecutiva e di realizzazione dei lavori sono iniziate il 1 Gennaio 2015 e sono terminate il 28 febbraio 2018.

Mentre la fase di studi e ricerche ha permesso di avere una visione d'insieme dello stato di salute dell'Oasi di Loiyangalani e dei suoi più immediati dintorni su una superficie di circa 390 ettari, è all'interno di questa più ampia area che si sono individuate cinque zone di intervento con progetti pilota che permettessero di sperimentare modalità realizzative basate su un approccio scientifico integrato ed interdisciplinare in relazione a:

1. Accesso all'acqua e realizzazione di nuovi punti di distribuzione;
2. Ricostruzione dell'ecosistema vegetale dell'Oasi in due aree, sia con palmeti produttivi che con piantagioni arboree ed arbustive;
3. Ricostruzione di aree destinate al pascolo;
4. Realizzazione di una nuova Nursery e impianto di compostaggio e di un edificio per Centro Monitoraggio e Documentazione.

I criteri per la scelta e localizzazione di queste aree differiscono in relazione alle condizioni ambientali rilevate (altimetria, morfologia, sistema di drenaggio naturale, suolo, vegetazione), alla vicinanza ad esistenti punti di presa d'acqua, alle necessità di parte dei residenti in Loiyangalani ed alle proprietà dei suoli.

Per l'accesso all'acqua e la realizzazione di nuovi punti di distribuzione, la scelta è ricaduta su una zona di 4.027m^2 (1,0 acri) posta a sud-ovest nello *'Wadi'* (o fiumara) in loco anche detto *'Laga',* in un ambito del villaggio abitato principalmente dall'etnia Turkana scarsamente dotato di punti di approvvigionamento idrico, dove sono state effettuate indagini geoelettriche per la perforazione del nuovo pozzo ed è stata localizzata la presenza di acqua. Il pozzo realizzato è stato connesso ad un sistema di distribuzione dell'acqua per gli abitanti del villaggio; dal pozzo, con una pompa ad energia solare l'acqua è portata in due serbatoi posti su un'area a quota più elevata e da qui, per caduta, tramite condotte, distribuita a questa parte occidentale di Loiyagalani con una fontana pubblica.

Per la ricostruzione dell'ecosistema vegetale dell'Oasi, a monte dell'Oasi (ad Est verso la Stazione di Polizia) in stretta adiacenza alla esistente vegetazione e vicino alle sorgenti, la scelta ha riguardato due aree tra loro confinanti caratterizzate da suoli non molto salini e da una forte perdita della cotica erbosa sia per erosione che per rarefazione e riduzione della struttura arbustiva ed arborea dell'Oasi. In un'area di circa 5.635m^2 (1.40 acri) è stata realizzata una *Palmeraie*, ovvero una coltivazione di Palma da dattero in consociazione con alberi da frutta ed orticoltura, mentre in un'area limitrofa di 3.379m^2 (0.83 acri) sono stati piantati arbusti ed alberi autoctoni per un ampliamento ecosistemico del sistema vegetale dell'Oasi, *Afforestation*.

Per la ricostruzione di aree destinate a pascolo, è stata individuata un'area di circa 8.395m^2 (2.01 acri) limitrofa alla pista di atterraggio ad Ovest, tutt'ora usata per il pascolo brado, caratterizzata da una forte perdita della cotica erbosa per sovra-pascolamento ed erosione; in quest'area è stata avviata e sviluppata la coltivazione di *Vetiveria zizanioides Linn.* o erba di Khas, per la produzione di foraggio per il bestiame da utilizzare in tempi di crisi-siccità. Si tratta di una pianta erbacea perenne della famiglia delle *Poaceae* originaria dell'India, ma che cresce molto bene anche in molte zone dell'Africa, cespitosa e sterile, assolutamente non infestante, che non produce stoloni o rizomi (si sviluppa solo per piantagione di rizomi e dunque non si corre il rischio di introdurre un'altra pianta 'aliena' infestante come la *Propospis juliflora* che sta distruggendo vaste aree del Kenya).

Per la realizzazione della nuova Nursery ed impianto di compostaggio con Centro di Monitoraggio e Documentazione (M&C Centre) o *Nanyori Area*, la scelta è caduta su un'area di circa 854m^2 (0,21 acri) ad Ovest, nella zona di sviluppo urbano, ovvero di frammistione di abitazioni tradizionali e nuove abitazioni con tetto in lamiera ed è limitrofa ad una Fontana pubblica di alta frequentazione e già usata dalla CBO locale Nanyori Group. Rappresenta anche una parte fortemente dinamica, con sviluppo preferenziale all'uso urbano della comunità Turkana. Gli interventi hanno riguardato la creazione di una

Nursery come centro per la produzione di piante da mettere a dimora nel corso del tempo in tutta l'Oasi, la realizzazione di un impianto di compostaggio da rifiuti organici per il miglioramento della fertilità del suolo, e di un edificio come centro per la gestione di tutti gli interventi realizzati e, si spera, di un loro ulteriore ampliamento.

Di fatto, la realizzazione di questo centro dovrebbe costituire il 'motore' della ricostruzione dell'Oasi ed essere punto di riferimento e luogo di aggregazione per tutti gli abitanti di Loiyangalani e per i villaggi El Molo con il principale obiettivo di diffondere la 'cultura' anche scientifica dell'intervento nel suo complesso, di ampliare gli skills tecnici per la coltivazione del palmeto e delle altre aree, la lavorazione e la commercializzazione dei prodotti, l'incremento delle risorse economiche, ecc.

Quattro delle cinque aree di intervento sono *common land* temporaneamente assegnate agli assegnatari dei fondi europei (VSF-Germany e WRF-Italy) dalla Contea di Marsabit nel Dicembre 2015 per la realizzazione degli interventi, mentre la quinta, quella per il M&C Centre è di proprietà privata e da tempo già assegnata al Nanyori Group CBO. Al termine del progetto (febbraio 2018) tutte le aree con gli interventi realizzati sono state restituite alla comunità con la cerimonia del '*Hand Over*'.

Infine, anche in linea con le indicazioni della *UNCCD-United Nations Convention to Combat Desertification*, un ruolo fondamentale per la buona riuscita del progetto è consistito anche e soprattutto nel Processo di responsabilizzazione delle popolazioni locali. A questo fine sono state svolte attività sia di *Information and Awareness* sui vari temi del progetto, al fine di coinvolgere gli abitanti, che sono i reali utenti di tutto l'intervento, nella realizzazione e poi nella gestione dei diversi progetti e nella loro espansione, che di *Tutoring and Training* svolte da esperti del *Baraka Agricultural College* (Nakuru) e dell'Associazione *Plus-Kenya* con un gruppo di persone appartenenti al Nanyori Group CBO ed al villaggio.

I cinque progetti nel loro insieme, sono, anche e soprattutto, il punto di partenza e una dimostrazione pratica di fattibilità per le autorità e le popolazioni locali che, una volta acquisite le tecniche e la capacità realizzative, potranno o dovranno applicarle a più vasta scala migliorando il suolo, espandendo le aree di consolidamento della vegetazione e gestendo la risorsa idrica nel suo complesso per espandere-allargare l'Ecosistema dell'Oasi, ad oggi in progressiva rarefazione, e per favorire uno sviluppo economico e sociale realmente sostenibile.

Infatti, l'uso delle tecniche agricole tradizionali e la loro integrazione con sistemi vegetazionali di alberi e arbusti non solo sembra essere la vera ed ultima risposta per la sopravvivenza di milioni di persone che vivono nelle zone aride del mondo ed una maggiore sicurezza alimentare, ma anche l'unica alternativa per contrastare efficacemente l'avanzata del deserto.

A Loiyangalani, nel ridotto limite spaziale e temporale a nostra disposizione, ci abbiamo provato, ma la strada è solo all'inizio e il percorso di cambiamento non solo ambientale, ma anche culturale e sociale non sarà breve. Qui magari per dover passare dalla cultura nomade a quella stanziale dell'agricoltore, in tante altre parti del mondo, quello industrializzato soprattutto, per dover passare dalla cultura dello spreco a quella della convivenza con i nostri limitati ecosistemi.

Si tratta di 'chiudere il cerchio', ovvero di dare opportunità agli uomini che vivono in queste terre di potervi rimanere mantenendo le loro identità culturali, importanti anche per l'ambiente che li ospita, e di trovare sinergie tra produzione di cibo e lotta alla desertificazione, tra conservazione delle risorse e nuove tecnologie adattabili alle '*traditonal knowledges*'.

Ancora una volta in questi luoghi che "danno un'idea abbastanza precisa di come doveva essere il mondo subito dopo la creazione del cielo e della terra"[2], l'uomo è al centro del cambiamento, nel male e nel bene. Alle origini quando da qui partì per allargarsi al mondo, oggi, forse, per dare una indicazione, una *road map* per affrontare un futuro diverso che si dovrà forzatamente evolvere verso situazioni di maggior equilibrio se si vuole che questo futuro sia ancora in mano agli uomini.

L'augurio è che le tre esse dell'area del Turkana '*A lanf od stones, snakes and scorpions*' possano ritrasformarsi in '*Loiyangalani*', ovvero, come ci ricordano e ci traducono gli anziani del villaggio, '*il luogo degli alberi*'.

Endnotes

[1] *Turkana Scientific Research Group- Firenze, Italy*: Lorenzo Vallerini, Architetto e Paesaggista, Dipartimento di Architettura-DIDA Università di Firenze, Responsabile del progetto e coordinatore scientifico; Giovanni Caponi, Geometra, Rilievi e cartografia; Marco Folini e Giancarlo Ceccanti, Geologi, Acquifera Onlus, Ricerca acque; Marco Mazzoni e Paolo Altemura, Chimici, Qualità dell'acqua; Piero Magazzini e Ugo Wolf, Agronomi-Pedologi.

[2] Moravia A. (2007), *La ragazza di Baragoi*, in A. Moravia *Lettere dal Sahara*,Bompiani Editore, Milano.

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