Growing trees on rock?
Restoration of Olive-Juniper Woodlands in Highland Eritrea:

Scott Jones[1]

SUMMARY AND BACKGROUND

This paper is a preliminary evaluation of a 21 year old effort to restore native forests on severely degraded land in highland Eritrea.

From 1991-95, the Eritrean Ministry of Agriculture (MoA), with funding from Norwegian People's Aid supported a unique, long-term experiment to explore ways of restoring upland areas of the Eritrean highlands that had become highly degraded or completely barren. The aim was to create practical options for self-reliance, poverty alleviation and sustainable use of woodlands through flexible, locally agreed approaches to land restoration.

Afromontane juniper-olive woodlands are one of the world's most threatened ecosystems. They used to extend on plateaux from northern Eritrea across northern Somalia, East Africa and Southern Africa almost as far as the Orange river (Hall 1984). Today few remnants remain. Most of these are heavily degraded. In Eritrea, almost all natural terrestrial habitats have been lost.

The Rora Habab plateau in the north of Eritrea contains the most northerly remnant of juniper-olive woodlands in Africa. Between the 1920s and the late 1980s, Rora's woodlands were disappearing at an alarming rate. Although they remain vulnerable, they were in the end saved by an Integrated Rural Development Programme during Eritrea's independence war, by the ending of that war in 1991, and through MoA and wider government of Eritrea (GoE) efforts to support the area and sustain local people's livelihoods. Stabilising parts of Rora is a major success story in reversing habitat loss and conserving woodlands that were on the verge of extinction.

In summer 1993, a series of permanent plots was established in three highland (2,400m) villages in Karneishem, 50km north of the capital, Asmara. The work was undertaken through the MoA and involved close collaboration with local people and administrations, the Ministry of Education and Norwegian People's Aid (NPA). Starting in 1991, almost 250,000 seedlings were grown in six nurseries, using olive and juniper seed from highland locations across Eritrea but avoiding seed from lower elevations, such as nearby Semienawi Bahri. Approaches were agreed to establish and protect eight experiments in Zagir, Weki and Deqseb. These included how to address seedling survival in extreme conditions. Several thousand seedlings were drought-hardened and planted out on exposed sites where just rock and regolith remained, where prospects for agriculture were non-existent, and all hope for restoration had been abandoned.

Twenty one years later, the author and a small MoA team undertook a preliminary evaluation of these areas. The sites have had varying degrees of protection. One site in Zagir had almost complete protection. Other sites were subject to grazing and cutting pressure (mainly for toothbrushes), especially of olive. Some farmers have protected olive trees. Others planted eucalyptus alongside them and allowed animals to graze.

[1] Dr Scott Jones is Director of Mind the Gap Research and Training, UK

Tree tree survival rates across all sites are 80-90%. In eight larger trees, birds nests can be found; one still had eggs. Several olives had flowers or fruits. Further evaluation is needed but preliminary results show that:

- It is possible to reforest heavily degraded lands using native olive and juniper.
- Olive and juniper seedlngs can survive, even when planted on fractured rock.
- All three species can seemingly co-exist with native olive, juniper and herbs growing well underneath eucalyptus, which provided harvestable timber after 12-15 years.
- Biodiversity increased in all sites.
- On one of the most challenging sites, a canopy has started to closed, providing a small refugium to show what can be achieved within one generation.
- Two key reasons for limited olive growth were opportunistic snapping of branches for toothbrushes, and grazing.
- Many local people were pleased with the results, conveying a real sense of achievement and possiblity, and even declaring one site 'holy' because they found it peaceful and beautiful, with many plants and birds after just over 20 years.

ORIGINAL PROJECT STRATEGY AND RESTORATION DESIGN

In 1991 only a handful of native juniper-olive woodlands remained in Eritrea. All had been heavily managed, modified for centuries, and remained subject to grazing and cutting pressures almost everywhere, except for protected sites such as churchyards and holy places. A restoration strategy was designed to respond to this crisis by creating flexible land use opportunities for individuals, communities and the MoA, through the permanent restoration of barren or degraded land. The goal was to design sustainable systems that ensured wood supply (e.g. from much valued eucalyptus) while enabling native forests to recover in ways that local communities could manage with some MoA support.

Ministry staff suggested several villages that might support a long-term experimental approach to woodland restoration. The Village Assembly of Zagir welcomed the project, provided that the village as a whole approved and that two neighbouring villages of Deqseb and Weki were involved. Possibilities were discussed with several hundred villagers in a public meeting. People were told that the experiments would tie up some of their land for many years and might not provide direct benefits for 20 years. They agreed to provide land and labour, and we started a 9-month planning process. The author moved to live in Zagir, relying heavily on the care and experience of MoA staff and community elders for technical, legal and contractual details locally. NPA maintained close interest and active support.

In 1992, using seed collected from Rora Habab and elsewhere in highland Eritrea, juniper, olive and eucalyptus plants were grown in dedicated plots in six nurseries throughout the country. Several experiments were then laid out in Zagir, Weki and Deqseb June - August 1993. These included:

- planting individual native trees in an agroforestry setting with one-year old olive trees as border plants around fields, and
- examining survival and growth of native olive and juniper in rock crevices, or on rock fractured with a crowbar, filled with a few centimetres of different soil/manure/ash combinations.

One of the core experiments consisted of plantings of single species and mixed stands using three species, two native, one exotic. The design enabled survival and growth characteristics of each species to be

examined under conditions of inter-specific and intra-specific competition in the following seven combinations, where:

- **J** = *Juniperus excelsa (Tsehedi, Ted, Nardet, East African Pencil Cedar, also J. procera)*
- **O** = *Olea cuspidata (Auwleah, Weiyra, Wegre, African Wild Olive, O. africana; O. europaea subsp. africana; O. europaea subsp. cuspidata)* , and
- **E** = *Eucalyptus cladocalyx (Kalamitos)*:

J only, **O** only, **E** only, **J**+**O**, **J**+**E**, **O**+**E**, and **J**+**O**+**E** (***Appendix One***)

Experiments took account of the different uses people had for native and non-native trees, the biological aspects of each species such as different growth rates, and their potential for coppicing and vegetative propagation. After many discussions with them and reference to Rora Habab data, village experts agreed the final species selection, based on ideas about shade, soil erosion control, diversity of uses, good quality construction timber, longer burning times, better smelling fuelwood, higher quality charcoal, termite resistance, superior agricultural tools (axe handles, ploughs etc.) and the 'loveliness' of the trees. Each combination was replicated in each of the three villages using a randomised block experimental design. The project was handed over to MoA staff and village authorities in 1995.

Gender and age were important aspects of project design in three ways. ***First***, roles, rights and responsibilities vis-à-vis natural resources differ in important ways among women and men, boys and girls. Therefore project design, permissions, knowledge-sharing and training ensured that:

- Women and men were consulted separately as well as together; formally within households and in village assemblies, and informally in day to day activities,
- Young people, men and women were included in the training on research design, planting and field work,
- Women as well as men were involved in, and paid for nursery and planting work, and
- A female trainer was fully involved in project design and implementation.

Prior to this, the author met with all sections of the community over the six months of his initial residence in Zagir before the project was agreed by the villages - a process that continued after project start.

Second, future decisions would likely involve questions about benefit distribution, including services (e.g. erosion control, shade), and products (e.g. agricutural tools, housing, fodder, fencing, toothbrushes, ornaments, household implements, handles). These issues were discussed and comparisons made between the gendered aspects of decision-making in Rora and Karneishem.

Third, gender and development were very much part of post-independence government thinking in Eritrea. Gendered aspects of community livelihoods, natural resource use, and enviromental restoration were discussed with the community and government representatives.

KEY FINDINGS

From our observations, key findings are:

Karneishem

1. It is possible to reforest heavily degraded lands using native olive and juniper. Survival of olive and juniper plants after 21 years was estimated at 80-90%. Where protected, it is possible to achieve growth rates of 25cm per year for olive, maybe more, and 40cm per year for juniper. Data on seedling growth for the first three years are still being analysed.
2. Olive and juniper seedlngs survived even on fractured rock, where small amounts of manure/ash (*deqwi/ hamaqueshtay*) had been added to local soil and placed in rock fractures for planting.
3. E. cladocalyx was on its second rotation, having been harvested from all the plots and sub plots.
4. E. cladocalyx did not, on our preliminary observations, retard the growth or form of olives or junipers growing under its canopy; all three species can seemingly co-exist without allelopathic or drought affects from the eucalyptus. Further soil and plant analyses would give a more complete picture.
5. Biodiversity increased in all sites. Where plants were protected, several herb species were in flower and seed. A litter layer and decomposition were observed in several microsites, most notably in Zagir and Weki. Eight birds nests were found, one in Zagir had two eggs.
6. A canopy had closed in one site at Zagir, with lower temperatures and more biodiversity under the canopy. This site was home to several bird species and birdsong could be heard in the treetops. Interestingly, this was the most challenging of all the sites we worked with back in 1993-5. We would have been pleased if even 10% of the trees survived and grew one metre in 20 years. As it is, we have a small refugium to show what can be achieved within one generation. In this site, three olives were in flower and one had seed.
7. The two key reasons for limited olive growth were opportunistic snapping of branches for toothbrushes, and grazing. Even on the most skeletal soils, most trees survived. Where they died, olives were mainly replaced with Dodonea viscosa (D. angustifolia) in Zagir, or eucalyptus elswehere.
8. Many local people were pleased with the results. It might not be stretching things too far to say that for some people, the work has been emotonally and spiritually uplifting, bringing a real sense of achievement and possiblity. Some landowners had invested in the juniper and olive trees as much as the eucalyptus, pruning and weeding around the trees; they were pleased to see us taking as much interest in the plants as they did themselves.

Beit Giorgis

Over 100 trees were selected based on phenotype charactersitics of form, growth rate, and root shoot ratios. These were re-potted separately and eventually grown on along the south side of Beit Giorgis nursery.

The heights of almost 100 olive trees planted in 1993 in Beit Giorgis were measured and are summarised below:

Measure (metre)	**Zone 1**	**Zone 2**	**Zone 3**	**Totals**
N	54	31	12	97
Mean height	4.07	3.58	1.73	3.62
Median height	4.16	3.80	1.47	3.85
Sx	1.08	1.37	1.07	1.39
Min height	1.38	0.40	0.74	0.40
Max height	6.30	5.78	4.50	6.30

The diameter at 1.3 metres height (dbh) of 43 of the bigger olives was measured (centmetres):

N= 43; Mean = 5.41; Median = 4.93; Sx = 1.49; minimum = 2.13; maximum = 8.53.

RECOMMENDATIONS AND ACTIONS

The MoA has demonstrated strong leadership within Eritrea and a commitment to finding sustainable solutions to afromontane woodland restoration in partnership with other African countries. The key recommendation is to develop a '*chain of stories'* that highlight the positive achievments so far and ensure that momentum is maintained regarding stabilising and restoring the vulnerable afromontane woodlands of Eritrea.

1. ***Undertake publicity and awareness-raising in Eritrea*** to highlight the government's commitment to these woodlands, the positive achievements in stabilising Rora Habab (a national and international treasure), the restoration experiments in Karneishem, and the achievements of some villagers in protecting and nurturing native tree species. This could involve an Asmara-based conference, including local leaders, administrations, youth, women and other key individuals from Rora, Karneishem, and other places.

2. ***Agree MoA operational decisions to protect existing sites and other areas***. This could include highlighting existing 'islands of biodiversity,' helping people protect key trees from toothbrush harvesting and grazing, and not killing insects, plants or other things in small protected areas or trial sites.

3. ***Undertake further evaluation***, including a participatory evaluation process, planned and agreed by the MoA to ensure that it is relevant, robust and scientifically sound.

4. ***Repeat the experiments*** in Karneishem, Rora Habab, Adi Keyeh

5. ***Seek engagement with partners for an international conference*** involving Tanzania, Kenya and Ethiopian colleagues working on afromontane woodlands (potentially Malawi, Zaire, Uganda), to raise awareness and explore further potential for regional collaboration.

6. ***Explore funding*** to quickly initiate international collaborations and raise awareness of Eritrea's success, building toward a bigger event within a year.

7. ***Produce a documentary***, building on the pilot documentary produced in August 2014 to include more Eritrean voices (Tigre and Tigrinya), more women, more youth and children.

8. ***Coordinate efforts for May 15th 2015 - National Greening Day*** - a major 'push' on native olive-juniper woodland restoration.

CONCLUSIONS

1. From the perspective of poverty alleviation and sustainable livelihoods, our experiments have demonstrated the possibility to successfully restore barren or heavily degraded land.

2. The experiment will continue to enable people to assess different options through time. Alternatives include (1) harvesting for woodfuel, alongside cottage industries based on the native species, and (2) harvesting eucalyptus completely, and leaving native species to grow to maturity, with full or partial restoration of native woodland. Given the situation at 21 years, local people and the MoA now have several options for future management.

3. It is possible to grow eucalyptus for fuelwood while native species regenerate alongside them. Assessment work in Rora Habab and elsewhere confirmed that eucalyptus and olive coppice well and that if juniper is well managed and carefully cut, it can survive and grow well, even with quite heavy lopping. We anticipated that the eucalyptus would rapidly over-top the native species. We now know that in mixed stands of eucalyptus and native species, the olive and/or the juniper are not outcompeted or killed by the eucalyptus.

4. Grasses and herbs have successfully colonised the land under the trees, compared to adjacent untreated, grazed hills. Agroforestry options and other opportunities have been created. Bird life and biodiversity in general has been enhanced.

In relation to climate change and livelihoods issues, it is now possible to more effectively evaluate how people now feel about the two following specific options that were discussed in developing the experiemental design 21 years ago.

A number of other options could now be explored in addition, based upon local people's views, the data and observations available to us, and the positive achievements of the MoA in reversing deforestation of native woodlands.

Option One Wood cutting and cottage industry

As the eucalyptus mature to harvestable size, they can continue to be cut to coppice at 20 cm or so, providing timber or fuelwood and releasing juniper and/or olive. Depending on the size they have reached the native species could then be thinned, or left to grow until they could be partially cut to provide wood for various locally made manufactures and for the many other uses they have; toothbrushes, roofing, agricultural tools, sticks etc. (Jones 1991).

Is it possible to develop a management plan in collaboration with local people? What might trees be used for now and over coming decades? Might it be more desirable for the plots to be managed as a continuous experiment, with wood, fodder leaves or toothbrush twigs harvested as the plants grow? Agroforestry may also be possible to maximise income potential from the same land. How feasible might it be to include light grazing, or growing annual crops under the trees once they are big enough?

Option Two Restoration and conservation option

Assuming some thinning, and a complete harvest and an eventual grubbing out of eucalyptus and any other exotics that have self-seeded (e.g. Prickly Pear cactus), several conservation options become possible following the release of the native species from competition with eucalyptus. If conservation is thought of as preserving native tree species and other plants only, there may be no reason why these could not be managed in similar ways to option (1) above. It may be that the trees could provide an economic return for local individuals or the community by selectively pruning limbs or tops to provide wood. Similarly, branches could be removed to provide fodder in times of shortfall of adequate grazing (e.g. drought), provided this was done sustainably.

However, it might also be possible to think of a broader approach to restoration/conservation, where the flora and fauna associated with the original afromontane juniper/olive woodlands were conserved along with olive and juniper trees. In this scenario, other native herbs, shrubs and grasses could be deliberately introduced as seeds or as young plants. A series of trials could range from simply leaving the juniper and olives to 'get on with it' with no other input, to importing soil inoculum, complete with seeds and microorganisms, under the olive/juniper cover.

Additional Possibilities for Peri-urban Areas

Lastly, and moving beyond the countryside to peri-urban situations, some of the barren, degraded lands around cities – even the capital, could be planted and protected to create recreation and nature reserves for residents and guests. This would fit with current plans to revitalise and refresh some of the areas within and around Eritrea's cities.

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Appendix One

Schematic representation of a restoration trial involving three species, *Olea cuspidata* (olive), *Juniperus excelsa* (juniper) and *Eucalyptus cladocalyx* established in each of three villages in Karneishem District, Eritrea, between 19 and 31 July 1993.

The purpose of the trial was to examine changes in ground cover and the survival and growth of each species under conditions of inter-specific and intra-specific competition. The following seven combinations of species were planted (O = olive, J = juniper, E = eucalyptus); J only, O only, E only, J+O, J+E, O+E, and J+O+E. For each of the seven combinations, at least 32 test plants were planted to allow for a 50% thinning after five or ten years, and because each of the combinations bordered on another combination when planted. Therefore, a border of the same type was needed to avoid interference from the adjacent combination.

KEY: (O = olive, J = juniper, E = eucalyptus). Each combination was replicated three times in each of the three villages. Average spacing between plants was 2.0 metres.

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Appendix Two

THE RESTORATION SITES

The sites were all within an area called Karneishem, in the villages of Weki, Deqseb and Zagir. Most families grew what they could on skeletal soils that barely supported people's food and fuel needs. Soil and water conservation were priorities for extension and funding. Land restoration using native trees had to be addressed in villages where food and fuelwood were already competing for land. The restoration described here was attempted on areas that were abandoned or almost bare.

Site assessment took place in 1991-3, at which time only four olives, three Rhus (Amus, Shamot, Qemo, *Rhus abyssinica, R. glutinosa*) and a dozen or so junipers were found outside of churchyards and holy places, across all of the highland Karneishem areas the researcher visited,. Restoration approaches therefore relied on assessments of other sites on the Rora Habab plateau.

The researcher visited Rora plateau annually, sometimes twice a year, between 1983 and 1994, living there between a few weeks and three months at a time, and working alongside the then Agricultural Commission and staff of the Rora Habab Integrated Rural Development Project. Oral histories about land use, woodlands, agriculture, and everyday life on Rora since the early 20th century was obtained from residents. Detailed vegetation and soil surveys were undertaken. Several cemeteries and one relict, densely wooded location also were surveyed. The researcher completed his BSc thesis (based mainly on the Abhaklu watershed in Bacla), and his PhD dissertation from his work across the plateau, focussing principally on Bacla, Beridge, Endlal, Shamotet and Laba, with smaller surveys in Rora Zagir and Rora Kayeh.

Climate data from Rora Habab and Karneishem were almost identical. Both are plateaux of gently undulating hills up to 2,650m elevation. Annual rainfall was highly variable 200 to 450 mm, sometimes more, with almost 80% falling in July and August. There is a dry season from mid October to March and sometimes a small rainy season around April and May. The higher elevations and slopes of both plateaux are sometimes covered with orographic cloud, especially between December and March. Mean annual temperatures are 18°C, with mean monthly temperatures ranging from 13°C (November to January) to 24°C (May to July). Temperatures rarely exceed 30°C. Pre-dawn temperatures in January are often 1°C to 3°C and mild frosts occur rarely. Potential evapo-transpiration exceeds precipitation in all months except July and August (Jones 1991a).

Both plateaux are composed of acid to intermediate volcanic rocks weathering mainly to near neutral pH, shallow, weakly developed, truncated, mainly grey, brown, yellow-brown and some reddish soils. On Rora, Ustorthents, Ustropepts, and Haplustalfs dominate, with very small areas of Ustifluvents near ephemeral streams and Haplustolls in uneroded areas. Soils are severely eroded almost everywhere, with B, BC and R horizons exposed. Boulders between 0.25m and 1m diameter occupy 50-100% of the soil surface on uncultivated slopes and ridges. Cobbles between 0.1m and 0.25m occupy 25-50% of the soil surface even in ploughed fields (Jones 1991a).

Before restoration, considerable effort was made to determine site history. The history of both areas is poorly known but a brief review for Rora suggests that the loss of woodlands there is comparatively recent. Oral testimony suggests the same for Karneishem. However, the histories differ in many ways and Karneishem had higher population densities and longer periods of settled agriculture than Rora, much of which was densely forested in 1900.

Shrub cover in Rora was dominated by *Dodonaea viscosa* (Tahses, Itacha, D viscosa subsp. angustifolia) and young, cut junipers. Other species present as shrubs were *Acacia origena* (Ch'aA!), *Carissa edulis* (Agam), *Maytenus arbutifolia* (Ergitteh, Argudi, Atat, *M. senegalensis*), *Nuxia congesta* (Atcharo), olive, Rhus, and *Tarchonanthus camphoratus* (Camphor bush, Sagewood, *T. abyssincus* . Cover of herbs and grasses ranged from 4% to 64%, averaging about 20%.

Rora's woodlands and forests decreased dramatically in area, density and diversity since about 1910. By the mid-1990s, the wild animal species recorded there up to 30 or 40 years ago could no longer be found, except for rabbits, although a survey would help to bring our knowledge of this situation up to date. Karneishem was most similar to southern Rora. Trees and many shrubs were virtually absent, areas of surviving woodland were patchy and occurred around churches and holy places (where cutting and grazing are prohibited) and in places that were uncultivable because of steep slopes or shallow soils.

LAND USE

Land use was based on private, family land tenure. About 20-35% of the land was used for wheat and barley production. Crops sown between June and July (May if early rains were adequate) were harvested after 90 to 120 days. Crop residues were grazed or ploughed into the soil by January. Mechanization and irrigation were not available. The Hababb people cut leafy olive branches to feed their animals, while Karneishem's residents travelled to escarpments nearby to cut olive branches for the same purpose and for toothbrushes. Tree seedlings and shrubs were browsed by livestock. Grazing was ubiquitous except when crops are growing.

All tree and several shrub species were cut for fuelwood and/or house construction. Wood was exported from Rora by licensed tree cutters, but charcoal was not made. On marriage, a man used to be able to take a number of juniper and olive trees, locally estimated to be about 30, to build a house. However Village Councils have restricted wood cutting and older houses are being renovated. In Karneishem, there are now more corrugated zinc roofs for new or refurbished buildings rather than earth and wood ones on traditional hdmo. There was no known tradition of tree planting on Rora until the mid 1980's, or in Karneishem until the Italian colonisation. However, trees were deliberately preserved in cemeteries in both places and by some farmers in fields and land near to their farms on Rora (Jones 1991a).