Trees and Watershed Management in Karamoja, Uganda

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Contents

List of Boxes

List of Figures

Acronyms

DFID	Department for International Development
FAO	Food and Agriculture Organization
FFS	Farmer Field School
FMNR	Farmer Managed Natural Regeneration
GIS	Geographic Information System
ICRAF	World Agroforestry Centre
IWM	Integrated Watershed Management
JWESSP	Joint Water and Environment Sector Support Program
LC	Local Council
MWE	Ministry of Water and Environment
NGO	Non-Governmental Organization
NRM	Natural Resource Management
RWUE	Rainwater Use Efficiency
WMZ	Water Management Zones

Executive summary

Karamoja is a dryland sub-region in north-east Uganda. Having suffered historical injustices, it now faces many difficulties, including civil and administrative challenges. Karamoja performs poorly on development indicators compared to other parts of Uganda: 82% of its population lives under the poverty line. Its infrastructure is underdeveloped, and the sub-region is troubled by climate variability and climate change. Drought and shifts in weather result in low agricultural productivity and declining rural production systems. Floods and droughts have had a particularly detrimental effect.

Moreover, Karamoja faces increasing environmental degradation, further threatening crop and livestock production. Trees are at the heart of Karamoja's ecology, providing livelihoods and nutrition for livestock and people when all else fails; trees also provide Karamoja with fundamental ecosystem services. Thus there is a need for evidence about the role that trees play in Karamoja. This document looks at trees in watershed management in the sub-region. Efficient water management may provide a large part of the solution to the current poor livelihood prospects in Karamoja.

From consultation with experts and a literature review, there is wide evidence of the benefits that trees confer to communities in Karamoja. We see various options for action with respect to trees in watershed management: the use of trees for flash flood control; erosion control and waterway fixation; resilient crop production; resilient livestock production; and efficient utilization of green water -- the precipitation that falls on the land, which does not run off into rivers, dams or groundwater but is absorbed into the soil.

Karamoja experiences frequent flash floods caused by water from heavy rains running from higher to lower lying areas. These can devastate lives and property, often sweeping away houses and farmlands. Ground-covering vegetation and trees can significantly reduce occurrence of flash floods. Trees allow for the infiltration of water into the soil. Therefore, this review strongly advises higher tree coverage in Karamoja's crop fields and rangelands.

Another benefit of trees is that they reduce erosion. They intercept rainfall, reducing the force with which drops strike the soil. Rainfall on bare land makes soil compact. The pores in the soil, which normally absorb the water, close; as a result, rainfall, instead of soaking into the soil, turns into runoff that often carries away valuable top soil, silting up streams, rivers and dams. This, in turn, harms the proper streaming of water. This review strongly recommends the maintenance, planting and regeneration of trees along riverbanks to control erosion.

Water management focuses on availability of blue water, the fresh surface and groundwater found in lakes, rivers or aquifers. While blue water is important, this review advises that green water is equally important. Most rainwater that falls goes to the creation of biomass. Green water is especially valuable for crop growth and livestock production, since it is easily taken up by biomass through the soil.

The use of trees needs to be mainstreamed in watershed management planning. Currently, many water resource management plans exist. An objective should be that watershed management organizations include trees in their planning. We advise that DFID develop capacity in organizations responsible for water management.

The authors suggest the following options for research, among others: research on the spatio-temporal variability in supply and use of and the demand for water in Karamoja. This would approach the water cycle from a social stakeholder perspective, which looks into inclusiveness, gender and equity; and a green and blue water perspective; which explores the effect of land use/cover change and irrigation on green and blue water cycles.

Other research questions arise from the question: what is the role of trees in the water cycle? What is their distribution? What are the trends in tree cover and species composition? What benefits do people derive? How does the planting, regeneration and management of trees and the removal of invasives support watersheds?

Further research would assess tree-based options and investigate institutions and interventions currently managing watersheds and trees. Apart from a socio-political perspective, it could examine the economics of tree-based interventions. Participatory research is vital: how do we mobilize farmers to work towards a positive future, and what is the role of indigenous knowledge in watershed management?

Research on trade-offs would focus on knowledge required to implement interventions to reduce damage by flash floods and reduce erosion. Research on trees for onsite resilient crop and livestock production will ask which trees are likely to contribute to multiple objectives on protecting the watershed as well as improving the resilience of production.

In addition, what are the most appropriate propagation methods and tree management practices for these priority trees? What are the appropriate tree species (both local and exotic) for watershed management as well as for a range of other benefits for the people of Karamoja? What are the appropriate tree-crop, tree-livestock, or tree, crop, livestock systems for the sub-region?

From the intervention proposed -- namely that trees should be increasingly included in watershed management -- there are many opportunities for Karamoja. Since trees can make a difference to the livelihoods of the people of Karamoja, it is important to take these action points into account when further planning management of the watershed.

SECTION 1

Introduction

In early November 2014, the World Agroforestry Centre (ICRAF) was approached by DFID Uganda through Evidence on Demand to provide a desk study on the role of trees in watershed management in the Karamoja sub-region of Uganda.

To develop the requested review report, ICRAF took the following steps. First, ICRAF constituted a multi-disciplinary team comprising the disciplines of agroforestry, water management, drylands, communications and a consultant knowledgeable on agroforestry in Uganda and the Karamoja sub-region. The team leader, a Principal Scientist in charge of drylands at ICRAF, led the drafting of a report outline that was shared with and consequently approved by DFID Uganda on the first of December 2014.

Second, the team searched the web and other sources for published information on trees and watersheds and other topics that were mentioned in the outline. This material, which included scientific publications, grey literature and other sources, was screened and reviewed and when found relevant included in this report with reference to the original source.

Effort was made to illustrate the report as much as possible with information and examples from Karamoja. Where this was not possible, information from elsewhere has been used. On December 15 a draft version of the report was shared with the Climate, Environment, Infrastructure and Livelihoods Professional Evidence and Applied Knowledge Services, and following inclusion of feedback received, the final version was submitted to DFID Uganda on December 17 2014.

The report was written between December 2 and December 15, 2014. Given this short period, the report does not aim to provide a comprehensive and rigorous analysis of the multiple relations between trees and watershed management in the Karamoja sub-region.

During the review, it was realized that there is a limited body of written information on the nexus of trees and watershed management in the Karamoja sub-region.
Because of this, the authors utilised their own research, field experiences, and observations in Karamoja and other dryland and agro-pastoral areas of Africa to provide a better picture of the role of trees in watersheds and their management in the Karamoja sub-region.

SECTION 2

Karamoja

2.1 General description

The Karamoja sub-region covers 27,511 km^2 and is located in the northeast of Uganda between 33^o and 35^o E and 1^o and 4^o N. The sub-region is made up of seven districts, namely: Abim, Amudat, Kaabong, Kotido, Moroto, Nakapiripirit and Napak districts. The population of Karamoja has been growing from the 171,945 people that were recorded during the 1959 census, to close to 988,429 people, according to the 2014 census[1]. The 2014 population of close to a million people corresponds to a population density of 36 people per km^{-2}.

2.2 Topography, climate and hydrology

The topography of the Karamoja sub-region is characterized by low elevation in the west and higher elevation in the east. There are also a few isolated mountains that consist of rocks of the crystalline basement complex[2]. These hills are largely the remains of much older mountains.

The weather in Karamoja is generally hot and dry. The average annual temperature is 21.5^oC; February and March are the hottest and July and August are the coolest months. Rainfall is unimodal with an annual average rainfall of 400 mm in the east and 1,000 mm in the west[3]. Analysis of 30 years of satellite imagery reveals an average length of the growing season 120 to 180 days, which is sufficient for dryland crops[4,5]. According to average annual rainfall, Karamoja is divided into three agro-climatic zones[6], namely the i) arid zone in the east with average rainfall below 500 mm, a prolonged dry season and highly erratic rainfall, ii) the semi-arid zone with an average annual rainfall of 500 – 800mm in the central part of Karamoja, and iii) the sub-humid zone in the west with an average annual rainfall of 700 – 1000 mm.

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1 Uganda National Bureau of Statistics-UBoS, 2006. Uganda - Demographic and Health Survey 2006; http://www.ubos.org/unda/index.php/catalog/26/sampling. Uganda National Bureau of Statistics- UBoS,, 2010. National Population and Housing Census 2014 Provisional Results. UBoS, Kampala. http://www.ubos.org/onlinefiles/uploads/ubos/nphc/nphc%202014%20provisional%20results%20report.pdf

2 Fris and Vollesen. 1998. Flora of the Sudan-Uganda Border east of the Nile. I. Catalogue of plants 1st part. Bioloiske Skrifter 51:1. The Royal Danish Academy of Sciences and Letters. Copenhagen.

3 Irish Aid, 2007. Chronic Poverty and Vulnerability in Karamoja: Synopsis of Findings, Recommendations and Conclusions, (Kampala: Irish Aid).

4 Njenga, M., de Leeuw, J., O'Neill, M., Ebanyat, P., Kinyanjui, M., Kimeu, P., Adirizak, H., Sijmons, K., Vrieling, A., Malesu, M., Oduor, A. and Dobie, P., 2014. The need for resilience in the drylands of Eastern Africa. In De Leeuw, J. et al. (Eds), Treesilience, an assessment of the resilience provided by trees in the drylands of Eastern Africa. ICRAF, Nairobi, Kenya, p. 5 -16

5 Vrieling, A., de Leeuw, J. and Said, M., 2013. Length of growing period over Africa: variability and trends from 30 years of NDVI time series. *Remote Sensing*, 5, 982-1000.

6 FAO at work in Karamoja. Supporting communities to build resilience. DRRU, FAO Uganda.

Rainfall is driven by convection of the air heated by the land, and the resulting thunderstorms frequently lead to torrential rains that, when discharged over denuded landscapes, result in floods and erosion. Average annual rainfall has decreased by about 15%, further compounded by the way in which the rainfall arrives; the intensity and the duration between rainfall events are unpredictable[7]. Cyclical droughts and erratic rainfall, which are expected to intensify under progressive climate change[8], affect crop production and pasture for livestock in the sub-region, thereby having a direct negative effect on the livelihoods of the population[9].

The drainage in the southern part of the region is dominated by deeply incised, sand filled, ephemeral channels flowing from east to west. These 'sand rivers', such as the Omanimani near Kangole, are a locally important source of water during the dry season when water can be found within a few meters of the surface. These channels feed into the southerly flowing Akokorio River via its tributaries, the Okok and Okere Rivers, leading through perennially swampy areas in its lower reaches and eventually draining to Lake Kyoga just to the southwest. Set on a large plateau, much of the Karamoja landscape is more than 1,000 m asl drains to the southwest or west. The Karamoja or Kapiri catchment mainly contributes to two seasonal rivers, River Okok and River Okere, which flow southwest into Akokorio River and drain into Lake Bisina. In the northern part of the Karamoja sub-region, particularly in Kaabong district, two rivers, the Kidepo and Narus flow, in a western direction through the southern portion of Kidepo Valley National Park. The Narus River eventually flows into Kidepo River about 30km to the west of the Uganda border with South Sudan. These two rivers provide valuable water resources for Kidepo valley.

[7] Anderson, I.M.A. and W.I. Robinson. 2009. Karamoja livelihood programme (KALIP): Technical Reference Guide. EU/ GOU/ FAO.

[8] Mubiri, D.N., 2010. Climate change and adaptation in Karamoja. FAO Uganda, 50 pp.

[9] Office of the Prime Minister-OPM 2009) Karamoja Action Plan for Food Security (2009 – 2014). Office of the Prime Minister, Kampala. http://opm.go.ug/assets/media/resources/17/Karamoja_Action_Plan_for_Food_Security_(2009-2014).pdf

Figure 1 Elevation and drainage for the Karamoja sub-region and surrounding areas

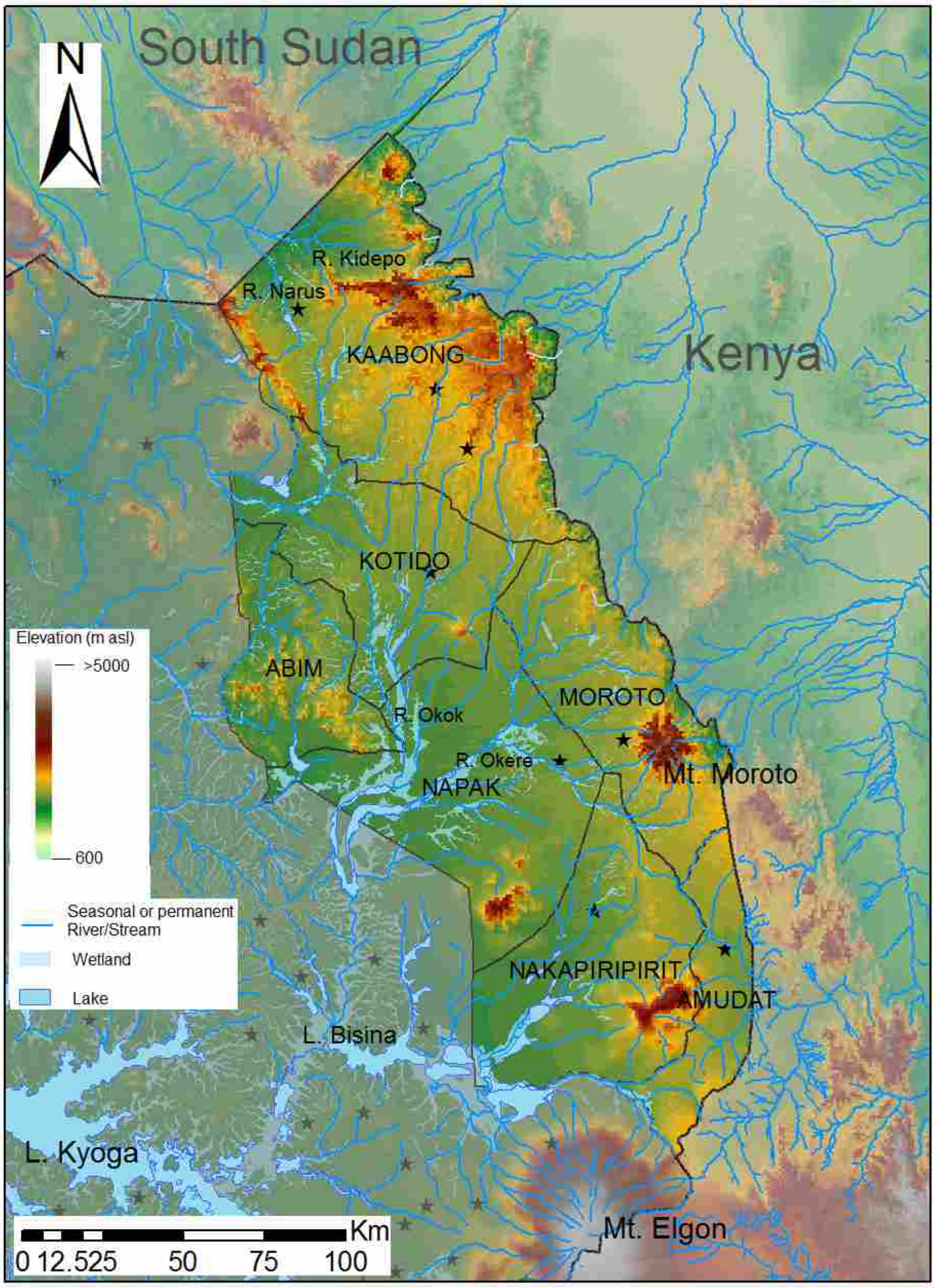
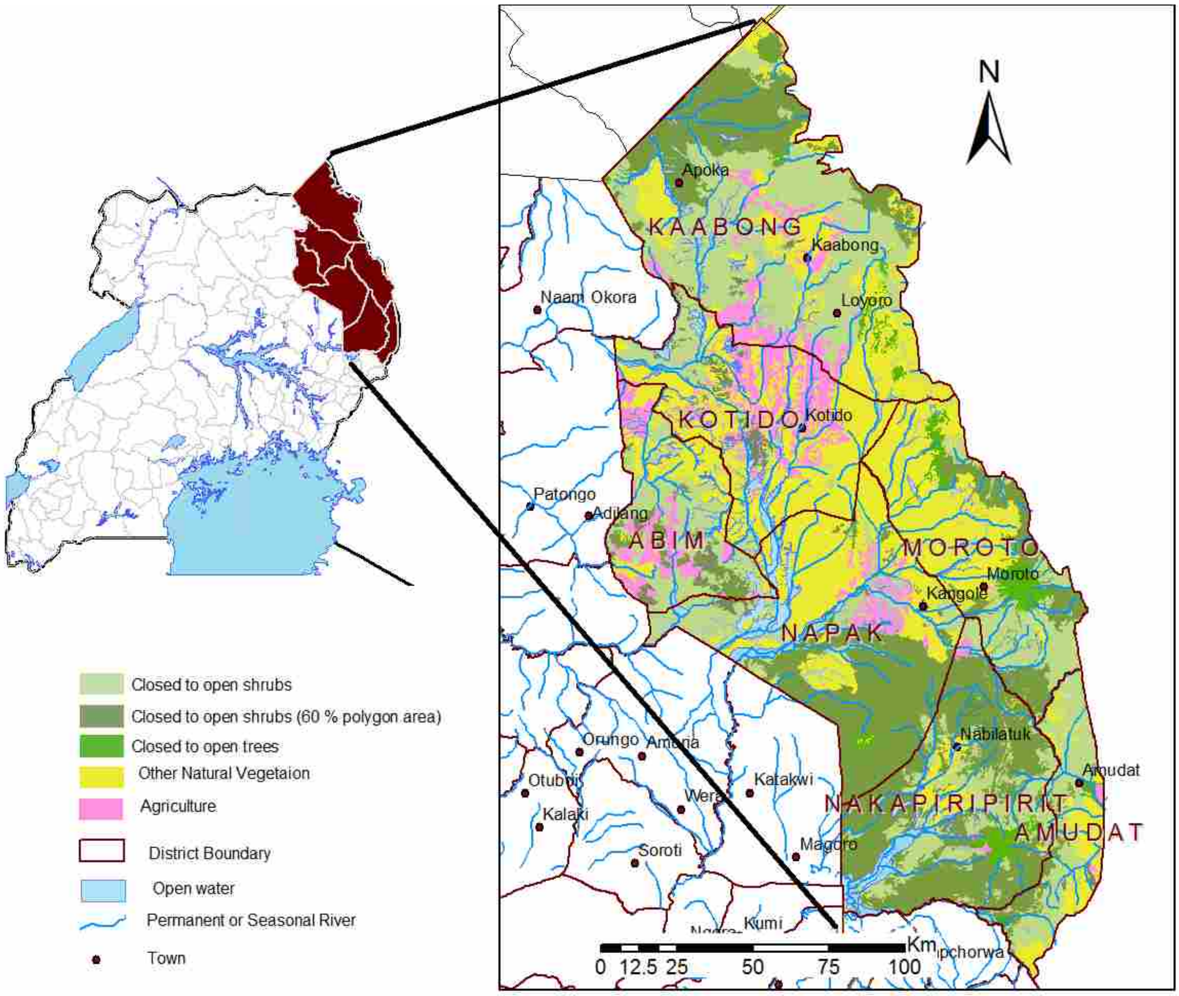


Figure 2 Land use for the Karamoja sub-region



Many of the streams and rivers in the sub-region are seasonal and dominated by a baseflow component for much of the year with a pattern of response, which correlates strongly with that of groundwater levels[10]. Whereas the sub-region generally receives low rainfall, the intensity of rainfall events is high resulting in high surface runoff that lasts 24 hours or longer after rainfall has ceased. In the head waters, river flows commence soon after rainfall starts with peak flows occurring in the afternoon or evening. River flows across the Karamoja plains occur from around April to August with flow in later months being fed by shallow groundwater flow from adjacent areas. There is a lag time of a month for upland flows to reach the dambos downstream of the Teso-Karamoja border which flow from May to October again supported by shallow groundwater flow long after the main rains have passed. The downstream rivers are then fed for another one or two months after upstream flows have ceased. Total surface outflow has been approximated as only 5% of the total catchment rainfall.

For effective management of the country's water resources, Uganda has been divided into water management zones (WMZ). The Karamoja sub-region falls in two water management zones, the Kyoga WMZ that drains to the south east into Lake Kyoga and the Upper Nile

10 Gavigan et al). Climate change impacts on groundwater recharge in NE Uganda and the potential role of groundwater development in livelihood adaptation and peacebuilding.

WMZ which take up the northern part of Karamoja where the streams flow west into South Sudan.

23 Livelihoods

Historically, the Karamojong were pastoralists, relying on livestock as their main source of subsistence. The landscape was composed of grasslands mixed with woodlands dominated by *Combretum* spp and *Terminalia* spp trees and wetlands and scattered fields[11]. Following growing population density, livestock alone no longer sufficed to support a fully pastoral way of life and consequently livelihoods in Karamoja began to change, gradually moving away from primarily relying on pastoralism to more diversified livelihoods. This diversification can be seen in the transition to[12], the proliferation of artisanal agro-pastoral livelihoods and the rapid adoption of crop-based agriculture mining of gold, marble and stones[13], and the adoption of charcoal trade and brick making[14]. The option of greater access to livestock markets, which could be pivotal for livelihoods, is impeded by trade prohibitions imposed due to frequent disease outbreaks[15].

11 Thomas, 1943, The Vegetation of the Karamoja District, Uganda: An Illustration of Biological Factors in Tropical Ecology. Journal of Ecology, Vol. 31(2): 149-177.

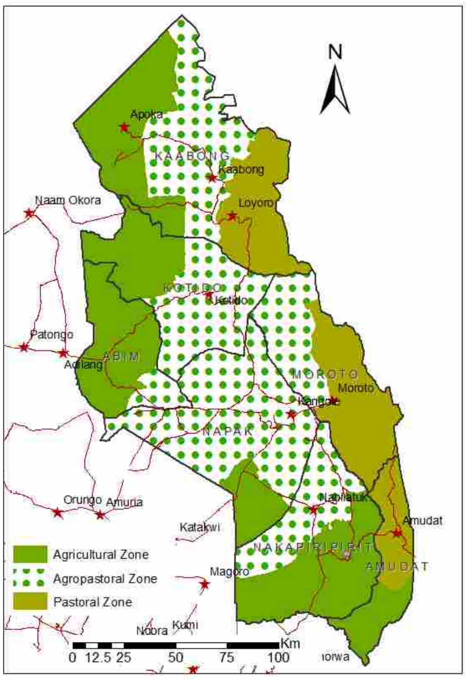
12 Egeru, A. 2014.Assessment of forage dynamics under variable climate in Karamoja sub-region of Uganda. PhD Thesis, University of Nairobi

13 Houdet J., Muloopa H., Ochieng C., Kutegeka S. and Nakangu B. 2014. Cost Benefi t Analysis of the Mining Sector in Karamoja, Uganda. Uganda: IUCN Uganda Country Office. ix +82p. http://www.synergiz.fr/wp-content/uploads/2014/05/CBA-Karamoja-Mining-Final-IUCN-ISS-Irishaid-Synergiz.pdf

14 Burns John Burns, J., Bekele, G. and Akabwai, D. 2013) Livelihood dynamics in northern Karamoja. A Participatory Baseline Study for the Growth Health and Governance Program. Mercy Corps and Tufts University, Boston.

15 Okurut, A.R.A and Eladu, F. 2013. Strategy for Livestock Development In Karamoja Region. Karamoja Livestock Development Forum (KLDF). http://www.disasterriskreduction.net/fileadmin/user_upload/drought/docs/Livestock%20Development%20Strategic%20Plan-KLDF%20(2014-2018).pdf

Figure 3 Livelihoods zone map of Karamoja. Source: http://map.u-map.it/



Karamoja is sub-divided into three livelihood zones[16] (Figure 2); (i) the Sub-humid Wet-Agricultural Zone, (ii) the semi-arid Agro-Pastoral Zone, and (iii) the Arid-Pastoral Zone. Each of these livelihood zones has defining attributes. The wet agricultural zone runs down the western part of the sub-region and receives the highest rainfall total in the region – on average 800 to 1200 mm per annum. The agro-pastoral zone represents the crop-livestock mixed farming system and runs through much of central to northern Karamoja with annual rainfall averaged at 500 to 800 mm, which is often poorly distributed. The arid-pastoral zone occurs in the eastern part of the sub-region, covering parts of Kotido, eastern Moroto and Amudat. This zone is characterised by variable, poorly distributed and low rainfall not exceeding 700 mm per annum[17]. Unlike most of the rest of the country, which has two rainy seasons and two planting seasons, Karamoja has only one rainy season and one planting season[18]. Karamoja is also characterised by high spatial-temporal variability in rainfall with a lack of a smooth transition from one extreme event to the other[19].

2.4 Land degradation, water and the need for Natural Resource Management (NRM)

Land degradation is widespread in Karamoja. It has been attributed to the traditional pastoral livestock grazing[20], but also results from the encroachment of agriculture and the adoption of crop monoculture. Land degradation further results from the excessive use of tree resources, which are increasingly overexploited to support livelihoods that depend on the sales of wood fuel and charcoal. Concern over land degradation is not new. For example, Wilson[21] mapped the soils of Karamoja in the 1950s and therefore can be considered an authoritative source; he reported widespread soil erosion in the sub-region. Some experts consider land degradation a biophysical process with emphasis on livestock grazing as an agent and human demography as a distant driver (e.g. Wilson, 1960). However, other experts place it

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16 Browne, S. and Glaeser, L. 2010. Livelihood Mapping And Zoning Exercise: Uganda A Special Report By The Famine Early Warning System Network (Fews Net). FEG Consulting/USAID.

17 GOU. 2009. Karamoja Action Plan for Food Security (2009-2014). Karamoja Agricultural and Pastoral Production Zones.

18 Office of the Prime Minister-OPM 2009) Karamoja Action Plan for Food Security (2009 – 2014). Office of the Prime Minister, Kampala. http://opm.go.ug/assets/media/resources/17/Karamoja_Action_Plan_for_Food_Security_(2009-2014).pdf

19 Egeru, A., Wasonga, O. Kyagulanyi, J., Mwanjalolo Majaliwa, G.J. MacOpiyo, L. and Mburu, j. 2014. Spatio-temporal dynamics of forage and land cover changes in Karamoja sub-region, Uganda. Pastoralism: Research, Policy and Practice 4:6. DOI: 10.1186/2041-7136-4-6.

20 Inselman, A.D.,2003. Environmental degradation and conflict in Karamoja, Uganda: the decline of a pastoral society. Int. J. Global Environmental Issues, 3: 168-187. http://www.inderscience.com/info/inarticle.php?artid=3863

21 Wilson, J.G. 1960. The soils of Karamoja district, Northern Province of Uganda. In: The Republic of Uganda. Memoirs of the Research Division. Series 1. Soils Vol. 2.

in a broader perspective -- the so called "Karamoja syndrome"-- that combines these factors with socio-political contexts of poverty, destitution, conflict and marginalization[22].

Land degradation, irrespective of the underlying drivers, affects the water cycle in various ways. The rainwater falling on the bare soils of degraded lands meets little resistance and typically runs off with great ease. This high run off in degraded lands results in flash floods, a common feature in Karamoja that is reported to destroy lives and property. It also results in erosion, which creates a number of problems. First of all, erosion washes away fertile and valuable soil, a resource that has developed over tens of thousands of years and is not quickly restored; thus erosion reduces the agricultural potential of the land. Second, erosion fills the rivers and streams with sediment, which in turn fills up reservoirs and small dams, thus reducing their longevity and undermining the investment in water storage infrastructure.

Uganda's land policy of 2013[23] recognizes that land degradation is a perennial problem in the country's cattle corridor which includes the Karamoja region and makes provisions for mechanisms to restore, maintain and monitor quality and productivity of land resources. In addition the Climate Policy[24] makes a provision to support on-going efforts to ensure climate change concerns are integrated into national efforts for sustainable and long-term conservation, access and effective utilisation and management of water resources. The policy emphasizes the need to promote and strengthen the conservation and protection against degradation of watersheds, water catchment areas, river banks and water bodies and well as the promotion of Integrated Water Resources Management (including underground water resources), and contingency planning for extreme events such as floods and drought.

Yet, while the above indicates that there is legislation to support land restoration, most government interventions in the Karamoja sub-region have emphasized disaster response to either provide food as a result of famine or help secure or save communities from flooding. There is however a significant area of land under conservation, including 19 Central Forest Reserves covering 11.6% of the sub-region and Kidepo Valley National Park, which covers 5.3% of Karamoja sub-region's land area. Other conservation areas, such as wildlife reserves and community wildlife areas, cover a further 35% of Karamoja's land[25]. Lake Opeta in the Pian Upe wildlife reserve is the only permanent wetland in Karamoja and of importance for the conservation of birds and the dry season grazing it provides for the cattle of certain Karamojong sub-groups and the Pokot people. This network of conservation areas is a key foundation through which to implement the protection of water catchment areas. There is, however, recognition that the setting aside of conservation areas often disposed livestock keepers of access to land and has aggravated conflict over scarce natural

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22 Kagan, S. Pedersen, L., Ollech, S. and Knaute, D. 2009. The Karamoja Syndrome: Trans-disciplinary systemsresearch informing policy and advocacy. ACTED. http://www.cultura21.net/karamoja/docs/Karamoja_syndrome.pdf

23 Ministry of Lands, Housing and Urban Development, 2013. The Uganda National Land Policy. Ministry of Lands, Housing and Urban Development, Kampala.

24 Ministry of Water and Environment-MWE. 2013. Uganda National Climate Change Policy. Ministry of Water and Environment, Kampala.

25 Rugadya, M.A., Kamusiime, H. and Eddie Nsamba-Gayiiya, E. 2010) Tenure in Mystery: Status of Land under Wildlife, Forestry and Mining Concessions in Karamoja Region, Uganda. Associates Research Uganda, Kampala.

19 Young and Sing'oie. 2011. Land, livelihoods and identities:Inter-community conflicts in East Africa.
http://www.operationspaix.net/DATA/DOCUMENT/6543~v~Land_Livelihoods_and_Identities__Inter-Community_Conflicts_in_East_Africa.pdf

resources in the remaining open access lands in the Karamoja sub-region as a whole[26]. These stresses leave people more vulnerable to natural and man-made disasters, and can intensify or trigger violent conflict and social instability. Some have argued that the gazetting of traditional grazing grounds and forests has disenfranchised communities and could have contributed to the high rates of degradation[27]. But loss of grazing land due to the creation of protected areas is only part of the picture. The Karamojong tradition of taking cattle westward to graze in the better watered Teso sub-region is no longer a widespread practice due to land use change and population growth in Teso as well as historical issues, specifically cattle raiding and other conflict in the 1980s and 1990s[19].

2.5 Rainwater Use

Water is considered a scarce commodity in Karamoja. Yet the total amount of rainfall in the sub-region is considerable. There is approximately 20,000 m^3 of rain per year available per capita, excellent by international standards. The Falkenmark Water Stress Indicator[28] considers a country to be water stressed when the amount of rainwater per capita is below 1700 m^3 per year. Karamoja is many times above this threshold. Hence it is not the amount of rain received by the sub-region that makes water scarce. There are other factors that contribute to the scarcity. The threshold of 1700 m^3 per person per year used by Falkenmark includes the water needed to sustain a society in its demands for blue and green water[29]. The green water is the water that infiltrates in the soil and is used by green plants for photosynthesis and the production of food and forage and other biological commodities for people and livestock.

In theory, the amount of water received over the Karamoja area could produce sufficient food if the rain were regular and distributed over a period long enough to allow the production of crops. In practice, rainfall is highly irregular, which makes rainfed crop agriculture risky in almost all but the wettest parts of the sub-region. Pastoral livestock keeping is considered to be a more resilient livelihood than crop husbandry in drylands; and indeed it was a sustainable livelihood for the Karamojong when human population densities were low. It is not a land use system that has the possibility to support the livelihoods of one million people in the sub-region. Mobile pastoralism typically supports human population densities of a few people per square kilometre, with a maximum observed in Narok district of Kenya of 10 people km^2, above which pastoralists settle and diversify into other activities including the production of crops.

The above clarifies why livelihoods in Karamoja are diversifying, with a trend towards agro pastoralism and crop-based agriculture. While the average amounts of rainfall in the semi arid and sub humid area are by themselves sufficient for crop production, what matters ultimately is the amount of water that is available in the soil to support the crop during its life cycle. Karamoja has a problem of irregular supply of rainwater and poor water infiltration that results in low and irregular soil moisture availability, which complicates the production of

26 Rugadya, M.A., Kamusiime, H. and Eddie Nsamba-Gayiiya, E. 2010) Tenure in Mystery: Status of Land under Wildlife, Forestry and Mining Concessions in Karamoja Region, Uganda. Associates Research Uganda, Kampala.

27 Magunda, m.m. 2010. Study on disaster risk management and Environment for the Karamoja Subregion. FAO Uganda, Kampala. http://www.fao.org/fileadmin/user_upload/drought/docs/Karamoja%20Disaster%20Risk%20Reduction.pdf

28 Falkenmark M, Lundqvist J and Widstrand C 1989 Macro-scale water scarcity requires micro-scale approaches. *Natural Resources Forum* **13** 258-67.

29 Rockstrom, J., et al. 2009. Future water availability for global food production: The potential of green water for increasing resilience to global change. Water Resources Research 45, http://onlinelibrary.wiley.com/doi/10.1029/2007WR006767/abstract

crops. The food insecurity in Karamoja has more to do with this irregular distribution of rainfall and soil moisture than with the total amount of rainfall per se.

There are other areas in the world, less well endowed with rainfall and with equally irregular rainfall, where farmers manage to produce crops. A crucial issue is how rainfall is partitioned over blue and green water. In semi arid areas with cropland surfaces devoid of any vegetation, rainwater easily evaporates and runs off, with little water infiltrating the soil to support the plants and their primary production to sustain crop based agricultural livelihoods and economies. It is estimated that the rainwater use efficiency (RWUE, the amount of rainfall used for primary production) in African drylands is between 5 and 15%, which is poor when compared to the RWUE reported from the USA and Australia in similar climatic conditions[30].

Rainwater harvesting is the term used for a series of techniques that are used to store rainwater for use in agriculture, sanitation or as drinking water for people and livestock[31,32]. Rainwater harvesting techniques vary in scale from large scale such as dams and reservoirs, to small scale structures as farm ponds or zai pits. Zai pits are successfully used to enhance the infiltration of water around the pit where seeds are planted with significant positive effect on the yield of crops planted. The above assessment of the amount of rainwater available per capita would suggest that the Karamoja sub-region has significant scope to increase crop production through the introduction of appropriate rainwater harvesting techniques. Several development organizations are already active in the promotion of rainwater harvesting[33]

The Karamoja sub-region has many dams and ponds. Yet, the manner in which the many were erected had less to do with wider natural resource conservation than the following influences: (i) a rapid response to drought challenges/water scarcity, so trees were little considered, (ii) a desire to reduce the distance travelled by pastoralists to water sources; and (iii) a concern to provide security for humans and safety for livestock. As a consequence, dams and ponds tend to have been developed close to the *manyattas*, the semi-permanent homesteads in which multiple families reside. Some manmade water bodies are relatively big in size -- such as Kobebe dam in Moroto district in the Matheniko game reserve, Nakicumet dam in Napak district, Nagoloapolon dam in Kotido district, and Nabbwalin in Kotido. Unfortunately, these water bodies are all substantially exposed to the strong winds prevailing in Karamoja; little if any deliberate effort has been exerted to shield them. Most of these dams also have technical inefficiencies with the result that, rather than water storage facilities, they resemble evaporation pans. Only a few dams have a tree shelter bay near them, such as the northern end of Lomogol. However, Lomogol dam is threatened by the cultivation (mostly sorghum) that surrounds it. Katukanyan dam in Kotido is largely still surrounded with tree cover as it was recently commissioned (July 2013). However, it too is threatened -- by firewood collection and charcoal harvesting. Most in the region are dams are highly exposed to strong prevailing winds thus high evapotranspiration

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30 Slegers, M.F.W. and Stroosnijder, L., 2008. Beyond the Desertification Narrative: A Framework for Agricultural Drought in Semi-arid East Africa. AMBIO A Journal of the Human Environment 37: 372-380.

31 Boers, Th. M. and Ben-Asher, J., 1982. A review of Rainwater Harvesting. Agricultural Water Management 5: 145-158. http://www.sciencedirect.com/science/article/pii/0378377482900038;

32 Wikipedia, Rainwater Harvesting; http://en.wikipedia.org/wiki/Rainwater_harvesting

33 Chow, J.T. 2012. Karamoja Water Harvesting Field Guide. ACF Water Harvesting Consultation. ACF-International.

leading to reduced residence time of water in the dam[34]. Other challenges include high sediment loading and siltation due to direct watering, high grazing intensity around the dam periphery, cutting of trees and soil erosion.

There is an initiative, under water for production project in Uganda's cattle corridor[35] to rehabilitate as well as construction new dams in the region, namely Kailong dam in Kotido District, Longoromit dam in Kaabong District, Arechet and Kobere dam in Moroto District and Kawomeri dam in Abim District.

34 Mugerwa, S., Kayiwa, S. , Egeru A. 2014. Status of Livestock Water Sources in Karamoja Sub-Region, Uganda. Resources and Environment 2014, 4(1): 58-66 DOI: 10.5923/j.re.20140401.07

35 Adaptation to climate change in Uganda http://www.gcca.eu/national-programmes/africa/gcca-uganda

SECTION 3

Watershed management

Watershed management is necessary to keep all the biophysical elements of a watershed functional or producing the vital ecosystem services. In most African countries, including Uganda, the removal of trees and other vegetation has resulted in the loss of ecosystem services more especially the production of clean fresh water. As defined by John Wesley Powell[36], a watershed is: "*that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community*."

Watershed management in Uganda is regulated by Policy Statement 8 on watershed management and soil conservation in the Uganda Forestry Policy of 2001[37].This policy statement sets out that “watershed protection forests will be established, rehabilitated and conserved”. The policy statement further stipulates that:

> *“The government will promote the rehabilitation and conservation of forests that protect the soil and water in the country's key watersheds and river systems. Achievements in watershed protection through forestry will result from the adoption of appropriate farm forestry methods on degraded private lands, from the improved management of natural forests on hilly private lands, and from the restoration of degraded hills on government lands.”*

Furthermore, strategies for the implementation of this policy statement will include the following actions:

1. Promote the rehabilitation of degraded forests in water catchment areas and bare hills through private, community and farm forestry initiatives.
2. Develop and promote guidelines on the management of riverside forests
3. Develop accompanying regulations to the provisions of the National Environment Statute (1995), the Water Statute (1995) and others, relating to watershed management, soil conservation and the protection of riverbanks and lakeshores.
4. Develop and promote awareness, educational and community mobilization programs to promote good integrated land use practices in hilly areas, and protect watersheds from degradation.

This policy is implemented through the Joint Water and Environment Sector Support Program (JWESSP) that is in its second phase of implementation for the 2013 – 2018 period. Implementation of JWESSP relies on the relevant directorates in the Ministry of Water and Environment (MWE), namely the Water Development-DWD, Water resources Development-DWRD and the Environment Affairs-DEA, together with semi-autonomous agencies such as the National Environmental Authority, the National Forest Authority-NFA and the Uganda National Environmental Authority-NEMA. Other key players include the Local governments that are in change of service delivery as well as Nongovernmental

36 Powell, J.W. What is a watershed? EPA, United States Environmental Protection Agency. http://water.epa.gov/type/watersheds/whatis.cfm

37 The Uganda Forestry Policy 2001. Ministry of Water, Lands, and Environment, Kampala, Uganda. http://www.sawlog.ug/downloads/The%20Uganda%20Forestry%20policy.pdf

Organizations-NGOs, Community Based Organizations-CBOs and the private sector. Structures at the local government level include a department of natural resources that has officers in charge of forestry, environment and water at the district level.

Following the establishment of catchment based water resources management by MWE in 2011, MMZ offices were established. With each of these, there has been piloting of catchment-based catchment based integrated water resources management is underway. The purpose of the Water Management Zone offices is to coordinate all water related development activities within the various catchments in each zones. The WMZ officer work together with local governments because all local level implementation of government programmes is carried out the district and parish level technical staff.

One of these, the Okok catchment, falls within the Karamoja sub-region (Box 3.Okok IWRM plan). Soil erosion was identified as a priority problem in the Lokok sub-catchment. Erosion is caused by a combination of torrential rains, porous soils that have poor water retention and a sloping landscape with rock outcrops, hills and mountains and a generally undulating landscape from north-east to the south, leading to rampant run-off. Overgrazing, tree cutting for charcoal, fires and poor cultivation practices also leave the land bare and prone to erosion. Soil erosion was also reported to be caused by prolonged drought that resulted in the loss of vegetation cover leaving the land bare.

Hence, while we found reference to the set up of institutions to manage watersheds we failed to find recent information on the status of watersheds in Karamoja. In order to determine the status, it would be necessary to undertake a detailed land use and land cover trend analysis using Geographic Information System (GIS) based tools and remote sensing to assess the pattern of land use change over time. In compiling this report, the team was unable to undertake this assessment due to the short duration of the assignment and limited budget.

However, the research team did look for historical efforts carried out by actors with a focus on the type and location of the action. One such effort captured is the action of the Food and Agriculture Organization (FAO) conducted in 2011 (See box with case study). What conclusions can be drawn from the FAO action? Given that this effort covered the entire Karamoja sub-region and that the action took place three years ago, two important conclusions can be come to. First, the entire sub-region urgently needs support to conserve the pressured and degrading watersheds. Second, the fact that a credible organization such as FAO found it prudent to organize a watershed management course to target key stakeholders drawn from all districts of the sub-region is an indication of the profound need for capacity to undertake the planning, implementation and monitoring of watersheds. It will thus be necessary for DFID to further explore the options of building on the efforts of the Government of Uganda, FAO and other stakeholders. The communities living in these landscapes should also be mobilized, sensitized and motivated to participate in conservation of their landscapes.

Box 1 Community based Integrated Watershed Management in Karamoja sub-region

The Food and Agricultural Organisation of the UN-FAO implemented community-based integrated watershed management in the Karamoja sub-region. FAO defines watershed management as the process of formulating and carrying out a course of action involving the manipulation of resources in a watershed to provide goods and services without adversely affecting the soil and water base. Usually, watershed management must consider the social, economic and institutional factors operating within and outside the watershed area.

Among other things, this project conducted a series of training events in Karamoja sub-region on Community-based Integrated Watershed Management in April 2011, training 31 participants, drawn from the seven districts of Karamoja, Kaabong, Kotido, Abim, Napak, Moroto, Nakapiripirit and Amudat. The approach of integrated watershed management was to help bring together all the various interventions that address water and degradation on the landscape.

An integrated programme approach takes into account land and water linkages within a natural ecosystem, the watershed. The training was aimed at enhancing the knowledge and skill of district local government and NGOs to plan, implement, monitor and evaluate community based integrated watershed management projects and programs. Under the framework of this project FAO worked with World Food Programme, District Local Governments and other development partners to pilot community-based integrated watershed management interventions in Karamoja.

Outcomes of the Effort

FAO introduced the Farmer Field School (FFS) approach in the sub-region. An evaluation of FFS in the Karamoja sub-region reported that soil and water conservation and tree conservation were included in season long trainings in several sub-counties in Karamoja. Furthermore, groups reported learning about soil erosion control using bunds, ditches and grass bands/strips, the damage caused by loss of tree cover. However, the report adds that there has been a challenge in adoption of these soil conservation techniques; only limited efforts appear to have been made to apply them.

Taking a watershed management approach to solving land degradation, water resources management projects require the active participation and involvement of all relevant stakeholders[38]. The range of participatory approaches to watershed management require a shift of attention not just to the ecology but also by the politics of natural resource management clearly defining who the beneficiaries are[39]. In addition to participation of stakeholders, integration of various disciplines is key to successful watershed management.

38 Carlos Perez, C. and Tschinkel, H. 2003. Improving watershed management in developing countries: a framework for prioritising sites and practices. ODI Agricultural Research & Extension Network Paper No. 129. Overseas Development Institute, London. ISBN 0 85003 676 3.

39 German, L., Mansoor H. b, Getachew Alemuc, Mazengiad, Amedee, W. T. Strouda A.. 2007. Participatory integrated watershed management: Evolution of concepts and methods in an ecoregional program of the eastern African highlands. Agricultural Systems 94(2):189–204. DOI:10.1016/j.agsy.2006.08.008

It has also been emphasized that local leadership needs to be trained to enable them to appreciate the benefits of integrated actions; in addition, feedback has to be sought from all stakeholders to help promote ownership of project or programme outcomes and improve stakeholder willingness to take on additional watershed management responsibilities[40]. A study was carried out in Ngenge watershed to the south of Karamoja to evaluate what it takes to obtain the full participation of stakeholders in watershed management (Box 2).

Box 2 Use of stakeholder analysis in integrated watershed management

Ngenge watershed is located on Mt Elgon area just south of Karamoja. Agricultural practices in the watershed cause serious soil erosion problems and subsequent decreases in soil and water quality. Attempts to manage soil erosion through policy interventions have not been successful; existing policies and legislation for natural resource management are inadequate and often formulated without consulting local communities. Subsequently, an integrated watershed management (IWM) program was initiated to foster sustainable land and water management solutions in Ngenge watershed.

A three-step approach was employed to identify key stakeholders and how they could be involved in the policy-making process in Ngenge watershed. The first stage was to identify the prevailing natural resource problems and all the stakeholders involved or affected. After identifying all natural resources management problems and stakeholders, the next step was to select the key stakeholders that should be involved in IWM.

Key stakeholder categories included local community, Local Councils (LCs), Sub Country Technical Staff and the District Administration. Other stakeholders identified were the central government ministries and departments, the community-based organizations and farmers associations, the private sector and external/neighboring communities that included the people in the Karamoja sub-region.

Presently resource management is undertaken by several different Governmental sectors, namely environment, forestry, agriculture, lands, wildlife etc. Their lack of coordination, however, renders the implementation of any intervention very complex. The local councils, however, are mandated to mobilize capacity and resources across these governmental sections for any intervention and therefore, this study by Mutenkanga et al 2013[41] recommended that implementation of integrated watershed management begin with empowering and involving local councils, particularly at the LC III and LC V levels. In addition, it was found important that other institutions working in the natural resources sector be sensitized so that they appreciate the need for appropriate resource management.

40 Liu, B.M.; Abebe, Y.; McHugh, O.V.; Collick, A.S.; Gebrekidan, B.; Steenhuis, T.S. 2008.Overcoming limited. information through participatory watershed management: Case study in Amhara, Ethiopia. Physics and Chemistry of the Earth 33 (1–2): 13–21.http://dx.doi.org/10.1016/j.pce.2007.04.017

41 Mutekanga, F. P., Kessler, A., Leber, K. and Saskia Visser, S. 2013.The Use of Stakeholder Analysis in Integrated Watershed Management. Mountain Research and Development. 33(2):122-131. http://dx.doi.org/10.1659/MRD-JOURNAL-D-12-00031.1

There have been several initiatives to promote watershed management in the Karamoja region. Many of these initiatives have taken sub-catchment scale or the parish level, which is the next local government jurisdiction after the village. A parish typically has 8-12 villages. Examples of these local-level planning approached to watershed management in the Karamoja region are provided in Box 3.

Box 3 Building resilience to drought through NRM in catchment areas

Since 2011 Action Against Hunger has been implementing an integrated water resources management project in Karamoja termed “Building resilience to drought through natural resources management in catchment areas”. The overall objective is to build resilience against drought through natural resources management. It is being implemented within the Lokok sub-catchment in Kotido, Napak, Abim, Kaabong and Moroto districts. The sub-catchment covers 5,512km^2 and is the largest seasonal river in the sub-region. Project achievements include implementation of ecosystem-based priority actions to strengthen social and ecological resilience; documentation and dissemination of best practices; and lessons on implementing integrated natural resources management plans in dry-land catchments.

Soil erosion was a priority problem caused by torrential rains, porous soils with poor water retention, and a generally undulating landscape from north-east to the south, leading to rampant run-off. Overgrazing, tree cutting for charcoal, fires and poor cultivation practices also leave the land bare. Soil erosion was also reported to be caused by prolonged dry spells that resulted in the loss of vegetation cover. It was recommended that tree planting programs be established with drought tolerant species. Check dams, gully plugging and tree planting were also recommended to restore overgrazed areas around water points, kraals and *manyattas.*

Lokok Catchment Management Framework: the IUCN, funded by European Humanitarian-ECHO, implemented the Lokok Catchment Management Framework at three sites - Mogoth, Moroto district; Koya, Abim district; Naponga, Kotido district. These cover 23 villages, 2500 households and 4500 people. Actions included zoning the parish into grazing land, farming land and highly degraded areas and riverbank restoration creating a 50m buffer on either side of streams and rivers with accompanying byelaws on no cultivation or cutting. There was also establishment of woodlots for fire wood, fruit gardens and live fences to reduce biomass off-take. Major lessons included the recognition that community participation is fundamental for success and building ownership. Also, watershed management must improve livelihoods and address governance.

The Mogoth Parish Rangeland Management Plan is an example of operationalizing the Lokok Catchment Management Framework. With a population of about 9000 in six settlements, Mogoth Parish had the same challenges as most of the sub-region including degradation of land around water points. The plan provides for i) a rangeland zoning scheme which addresses existing and emerging competitive land uses, including settlement, livestock grazing, crop cultivation and degraded riverbanks restoration, ii) an integrated rangeland management approach to restore degraded rangeland areas, and iii) decision making structures to bridge the local bodies with the political and government administration to set and implement environmental regulations. The objective is to strengthen and empower communities to manage their water and rangeland resources and build their resilience to drought through integrated water resources management and sustainable rangeland natural resource management

The Naponga Parish Water Resources Management Plan was developed for 2011-2016. Naponga Parish is in Rengen Sub-County, Kotido, and characterised by low water availability for its 3200 inhabitants due to seasonality of all its rivers. This plan proposes a range of activities: i) establishing homesteads and settlements and the associated capital infrastructure, ii) promoting irrigated agriculture and vegetable gardens, iii) rain water harvesting from River Dopeth, streams and ponds for domestic use, irrigation and livestock, iv) bylaws limiting where animals are to be grazed v) promoting live fencing of all homesteads and demarcation of farmlands with live trees and vi) establishing village woodlots and household fruit orchards.

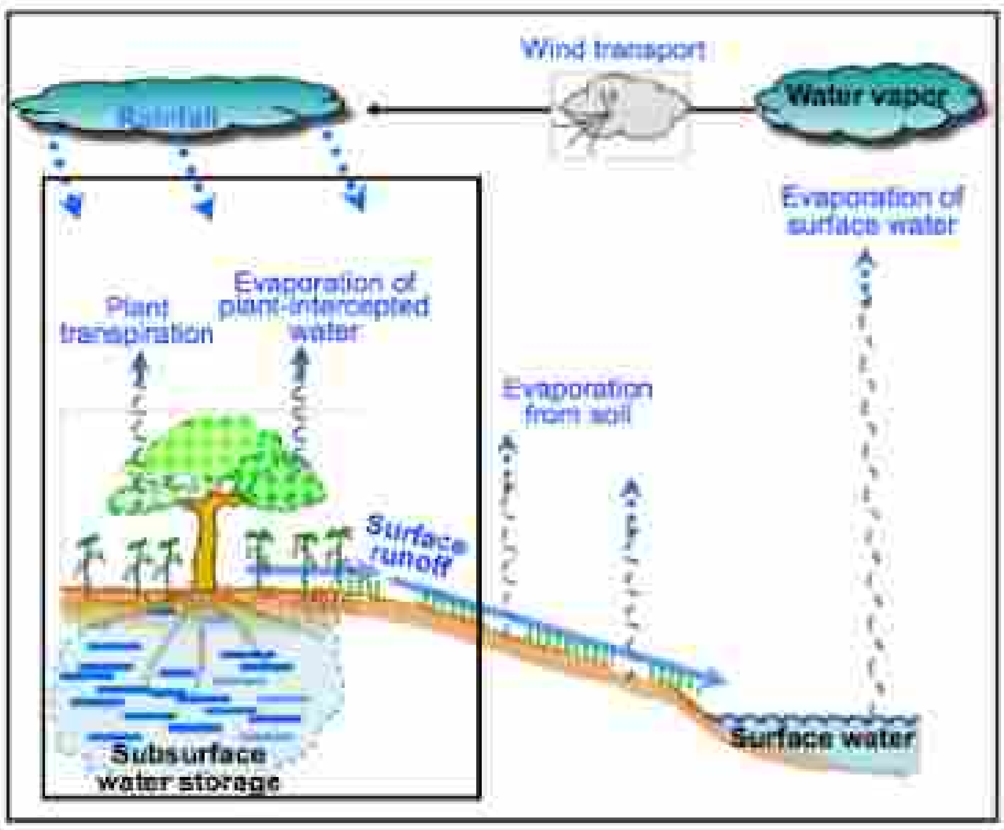
Several initiatives are underway to address challenges using the watershed management approach. Most involve components of tree planting or some other form of tree management to protect the landscape from degradation as well as to secure water resources for domestic and other uses. One of the challenges faced during tree establishment in a semi-arid area like Karamoja is identifying the most suitable tree species as well as ensuring survival of planted trees. The latter are mainly threated by drought or browsing by livestock and wildlife.

SECTION 4

Role of trees in water cycle

Trees affect the water cycle in many ways (Figure 4). Trees intercept and store water with and within their canopies, direct water to the soil with their trunks and roots, and transpire water back to the atmosphere. They influence hydrological processes such as rainfall, infiltration and run off, and evapotranspiration, and they interact with groundwater not accessible to other shallower rooting vegetation. They also influence the availability of soil moisture to other plants and ameliorate the microclimate of plants growing in their neighborhood. Trees influence the amount of rainwater running off and erosion and have significant effects on downstream hydrology. This chapter reviews the various effects of trees on the local water balance locally and across watersheds.

Figure 4 The water cycle: bolded script stands for storages, and blue script and arrows stand for processes. Inset: the role of trees (From Safriel, 2014)



Trees influence rainfall in two ways. First, trees may increase rainfall because their leaves are dark, and hence have a lower albedo (fraction of sunlight reflected) than drylands soils, which are mostly pale[42]. Low albedo surfaces such as trees absorb more solar energy and heat up more than high albedo surfaces. This heat drives the convection of air, which triggers the formation of cumuli clouds and rainfall. Increase in rainfall in the northern Negev of Israel has been attributed to reduced albedo resulting from transformation of rangelands to afforested and irrigated cropland systems[43], while Samain et al.[44] attribute increased rainfall in the Sahel to albedo changes. Second, tree and forest vegetation transpire more moisture than any other vegetation or bare soil. They humidify the air, which may contribute to the formation of rain. As a consequence, reducing forest and tree cover may lead to reduced flows of moisture to the atmosphere[45,46] and reduced rainfall. In drylands the albedo effect is probably more important; it has been described for other drylands and has an effect on the rainfall on site. The positive effect of atmospheric humidification has been described for tropical rainforests; it is not clear how much dryland forests contribute to this, and the effect is not necessarily local but may be felt far away from the source.

Once rain is falling, it may either fall through (throughfall) and reach the ground or be intercepted by the trees' branches, trunk and leaves. The rain intercepted by these tree surfaces either evaporates (interception loss), drips to the ground (canopy drip), and/or flows down branches and stems to the ground (stem flow). The "interception loss", which may be considerable, is even higher when considering water in the litter layer under the canopy as part of the tree surface. Two juniper tree species in US rangelands had interception losses of 26% and 37%. This increased by 40% and 60% when the interception loss attributable to litter was included[47]. While intercepting rainfall, trees reduce the impact of raindrops on the soil and thereby reduce compaction of soil, run off and erosion and enhance infiltration and water stored in the soil.

When water arrives at the soil surface, trees, through their roots and the activity of animals associated with these, may open the soil thus enhancing porosity and the rate of infiltration of water in the soil[48] (See box). Because of their rough surfaces and porous structure, soils under trees will generally have higher infiltration than soils overlain by other vegetation types[49]. These processes help to reduce runoff, which in places like the Karamoja sub-region have had devastating consequences such as erosion and damage caused by flash

[42] Safriel, U., 2014. The water regulation service of dryland agroforestry ecosystem. In: De Leeuw, J., Njenga, M., Wagner, B. and Iiayama, M. (Eds.). Treesilience. An assessment of the resilience provided by trees in the drylands of Eastern Africa. World Agroforestry Centre (ICRAF), Nairobi, pp. 104-109.

[43] Otterman, J., et al., 1990. An increase of early rains in southern Israel following land-use change. Boundary-Layer Meteorology 53: 333-351.

[44] Samain, O., et al., 2008. Analysis of the in situ and MODIS albedo variability at multiple timescales in the Sahel. Journal of Geophysical Research-Atmospheres, 2008. 113(D14).

[45] Sheil, D. and D. Murdiyarso, D. 2009. How forests attract rain: an examination of a new hypothesis. Bioscience, 59: 341–347.

[46] Sheil, D., 2014. How plants water our planet: advances and imperatives. Trends in Plant Science, 19 (4): DOI:10.1016/j.tplants.2014.01.002.

[47] Thomas, L.T. and J.W. Hester. 1997. How an increase or reduction in Juniper cover alters rangeland hydrology. In: Juniper Symposium Proceedings; Juniper Ecology and Management.

[48] Bargués Tobella, A. et al. 2014. The effect of trees on preferential flow and soil infiltrability in an agroforestry parkland in semiarid Burkina Faso. Water Resources Research 50; DOI: 10.1002/2013WR015197

[49] Swallow, B., Dennis P. Garrity, D. P., van Noordwijk, M. 2001. The effects of scales, flows and filters on property rights and collective action in watershed management. CAPRi Working Paper No. 16. CGIAR System-wide Program on Collective Action and Property Rights-CAPRi, IPFRI. http://www.capri.cgiar.org/pdf/capriwp16.pdf

floods. For example, Young[50] reported more than a tenfold reduction in runoff under trees compared to cultivated fields.

The previous paragraph suggests that the promotion of tree cover is likely to have an effect of reducing run off and the associated damage caused by flash floods and erosion. This is an important potential benefit of trees in drylands like Karamoja because the sub-region is plagued by flash floods and erosion. A web search on flash floods and Karamoja reveals several messages on damage caused by flash floods to roads, vehicles, houses and lives of people. The Ugandan Observer of November 16, 2013 for example reported that flash floods caused by torrential rains had destroyed roads and cut off Karamoja.

Trees have the potential to reduce soil erosion in the landscape through a range or processes. This effect on erosion is attributable to the reduced impact of raindrops on soil particles that is caused by the interception of rain, the reduced run off attributable to greater infiltration that was reported above and tree roots holding the soil particles in place. Erosion reduction is necessary in Karamoja given the high land degradation reported in Chapter 2 and the risk of reservoirs filling up because of the high sediment loads of the sub-region's ephemeral rivers. Among NGOs and agencies, the World Food Programme is active in Karamoja in erosion control using a number of physical techniques (stone bunds) and trees and shrubs to increase water retention[51]. We are not aware of any existing knowledge to determine which trees are best suited to control erosion in specific situations. Several factors need to be considered when assessing the effectiveness of trees in reducing erosion. These include the effect of the species on the interception of rain water, as well as its infiltration enhancing and soil binding effect. Additional variables to consider are the trees' rate of growth and root biomass; faster growing trees with higher root biomass will be more effective in reducing erosion[52]. A good example is the *Faidherbia albida* tree that has been widely planted across sub-Saharan Africa[53].

With their deep roots, trees are able to access water in deeper soil horizons that are beyond reach of shallow rooted vegetation. They are also able to lift water from lower to higher soil horizons (hydraulic lift and redistribution) and thereby facilitate the availability of water to crops and grasses. This effect of trees was recently reviewed by Wilson and Ndufa[54] who concluded that while trees generally positively influence overall productivity of dryland ecosystems, they also affect the growth of crops and grasses in their vicinity, through effects on soil nutrients, above-ground micro-climate and soil moisture. The exact effect of trees on crops grown in their vicinity depends on the crop and the tree species and the way it is managed. For example, farmers in the West African Sahel prune the roots of the shea butter tree (*Butyrospermum paradoxum*) to reduce completion with millet and sorghum. Yet, even in situations where trees compete with crops, livelihoods benefit because the ensemble of the production and diversity of foods and other commodities delivered in a mixed tree crop system is always greater than in crop monocultures.

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50 Young, A. 1989. Agroforestry for Soil Conservation, ICRAF, Nairobi.

51 World Food Programme (WFP), 2012. Evaluation Report Title: Formative Evaluation of WFP Livelihoods Programme in Karamoja. Web site accessed 14 December 2014; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/204625/WFP-livelihoods-prog-Karamoja-Uganda-man-response.pdf

52 Bromhead, M.A. 2012. Forest, Trees, and Woodlands in Africa : An Action Plan for World Bank Engagement. Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/11927

53 World Agroforestry Centre (ICRAF). "Unique Acacia Tree's Promise to Revive African Soils." ScienceDaily, 26 August 2009 www.sciencedaily.com/releases/2009/08/090824182535.htm

54 Wilson, J. and Ndufa, J., 2014. Soil moisture. In: De Leeuw, J., Njenga, M., Wagner, B. and Iiayama, M. (Eds.). Treesilience. An assessment of the resilience provided by trees in the drylands of Eastern Africa. World Agroforestry Centre (ICRAF), Nairobi, pp. 91-95.

Trees influence microclimate and may reduce the evaporative demand for species under their canopy. Muthuri et al.[55] recently reviewed the microclimatic effects of trees and the benefits of crops and forage grasses growing in their vicinity. There are many cases where positive effects have been reported but the authors conclude that attempts to reproduce these benefits by introducing agroforestry in similar environments have often been disappointing. They attribute this to the situation specific context: soils, climate, trees, crops and animals are location specific, and practices developed in one region may not be suited to soil fauna and flora of a different region. Hence, proper consideration needs to be given to the context where positive effects have been reported, before considering outscaling to another environment. As a result of greater storage of water in soils under trees, trees have been reported to increase base flow of river water because soils under trees store more water. Consequently, removal of tree and forest cover will increase water yield[56],[57]. This effect has been described for humid forests; its relevance in drylands forests is unknown.

Thus far we have discussed the influence of trees on the water cycle. The water cycle also influences trees. Their production and vitality is influenced by the amount of water available and shortages of water result in decreased production and possible mortality. Young trees in particular are prone to water shortages and there is ample experience that planting of trees is problematic in the drier parts of the sub-region, where survival rates of trees are sometimes disappointing. The water scarcity related low survival of planted tree seedlings is further reduced in areas where livestock graze, which is common in most of Karamoja, and hence the planting of trees is advised in areas where supplementary water can be provided and seedlings can be protected from livestock. One option is to combine the planting of trees with small-scale rainwater harvesting techniques that concentrate rainwater to the planting pit and increase the availability of water with positive effects of tree survival rates. Another option is to promote livestock exclosures, which have been implemented with success i Ethiopia, Tanzania and Kenya. Here, areas of land are shielded off from livestock grazing to allow trees and other vegetation to reestablish. This is one way of Farmer Managed Natural Regeneration (FMNR) a technique that relies on the regeneration rather than the planting of trees[58,59].

Above we have described a variety of processes whereby trees interact with the water cycle. Many of the processes are local and the benefits of these are also experienced locally. Some processes like the increased base flow and reduced flood and sediment loads bear over wider areas and connect the upper and lower parts of catchments.

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55 Muthuri, C., Bayala, J., Iiyama, M. and Ong, C. 2014. Trees and microclimate. In: De Leeuw, J., Njenga, M., Wagner, B. and Iiayama, M. (Eds.). Treesilience. An assessment of the resilience provided by trees in the drylands of Eastern Africa. World Agroforestry Centre (ICRAF), Nairobi, pp. 98-102.

56 Stickler et al 2013. Dependence of hydropower energy generation on forests in the Amazon Basin at local and regional scales. PNAS, 110: 9601–9606

57 Sun et al. 2014. Effects of timber management on the hydrology of wetland forests in the southern United States.

58 Rinaudo,T. with World Vision and SIM. A short history of farmer managed natural regeneration The Niger Experience. ECHO Technical Note, 2010

59 CGIAR Research Program on Water, Land and Ecosystems. Agriculture and Ecosystems blog by http://wle.cgiar.org/blogs/2013/11/12/bringing-land-back-to-life-farmer-managed-natural-resource-generation/

SECTION 5

Options for research

Following the previous sections and considering the proposed options for action that are described in section six, the authors of this report consider that there are the following options for research:

1. **Water in Karamoja**. What is the spatio-temporal variability in supply of, the use and the demand for water resources in the Karamoja sub-region? Who are the stakeholders and how do they benefit? And how can these water resources be managed to enhance economic development and reduce vulnerability to drought and flooding in the sub-region? This research would approach the water cycle from multiple perspectives: a social stakeholder perspective, which would critically look into inclusiveness, gender and equity; and a green and blue water perspective; which would look into the effect of land use/cover change and irrigation on green and blue water cycles, and how irrigation based options might affect the benefits of current water users.

2. **Trees in Karamoja.** What is the role of trees in the water cycle and what is the distribution of trees in Karamoja? What are the trends in tree cover and tree species composition? What benefits do people derive from trees on site and across the larger watershed? How can the planting and regeneration of trees, tree management and the removal of invasive species support land restoration and watershed management?

3. **Watershed management.** This research would investigate the current institutions and interventions targeted at watershed management, the inclusion of trees in these policy instruments and assess options and what needs to be done for implementation of tree-based options in the already existing enabling policy environment. Apart from a socio-political perspective, it could also look into the economics of tree-based interventions. Further, it would look into options for participatory research: how do we mobilize farmers to envision and work towards a positive future, and what would be the role of indigenous knowledge and skills of farmers in using trees for watershed management?

4. **Trees to manage off-site trade-offs.** This research would focus on knowledge required to implement interventions to reduce damage by flash floods and reduce the negative impacts of erosion. It would investigate: which areas are affected by flash floods? What personal and economic damage do they create? What tree-based mitigation options exist? And how much damage reduction could be achieved? What are the economics of tree-based interventions and what policies and institutions are required to support an agenda to reduce damage from flash floods? It would also investigate: Which areas are affected by erosion? What tree-based mitigation options exist? How much loss and damage could be prevented by them? What are the economics of tree-based interventions and what policies and institutions are required to support implementing an agenda to reduce losses attributable to erosion? And what are the major drivers of erosion?

5. **Trees for onsite resilient crop and livestock production**. Which trees are likely to contribute to multiple objectives on protecting the watershed as well as improve resilience of crop and animal production? What are the most appropriate propagation methods and tree management practices for these priority trees? What are the appropriate tree species (both local and imported) for watershed management as well as for a range of other benefits for the people of Karamoja? What are the appropriate tree-crop, tree-livestock, or tree, crop, livestock systems for the sub-region?

SECTION 6

Options for action

Given the previous sections, we advise DFID and development partners to consider the following options for action:

1. **Support institutions responsible for watershed management**. Watershed management is addressed by various arms of government. At this moment, there is a lack of an institution responsible for integrated watershed management, which brings together the various sectoral approaches. Such an institution would require a mandate and the capacity to implement policy. This would include capacity in collection, archiving and analysis of data relevant for watershed management, e.g. basic hydrological variables, information on water demand and water use, including social perspectives on equity and gender, the effects of use on the availability of water across the watershed and its various stakeholders, and the capacity to stimulate a dialogue to discuss and negotiate a fair distribution of water. Obviously, such an institution would require the capacity to assess the role of trees in watershed management and implement tree-based watershed options as discussed below. It would be wise to look into the economics of promoting trees across watersheds, including investments, benefits and trade-offs. Such efforts will need to build upon existing work done by organisations such as ACTED. Capacity of district technical staff needs to be enhanced so they can help in the collection of data. Data collected will have to be shared with the Northern Uganda Data Centre-NUDC[60] in the Office of the Prime Minister.

2. **Mainstreaming green and blue water management**. Traditional water management solely considers the blue water available in surface and groundwater. This leaves out the green water that drives primary production, which results in the provisioning of foods and other biodiversity dependent ecosystem services. The lack of knowledge and neglect of green water reduces the ability of NRM managers to assess how land use affects the partitioning of rainwater over green and blue water resources. That constitutes critical information to adequately decide on the development of interventions that affect the water cycle. We propose to support institutions involved in water management to develop and implement capacity to comprehensively assess blue and green resources in order to proactively respond to the effects of ongoing processes and proposed interventions in the water cycle.

3. **Mainstreaming trees in watershed management planning**. Trees are generally considered positively in watershed management planning, yet there is need to translate intentions and proposals to promote trees into interventions that deliver on positive environmental and livelihood outcomes. Various water resources management plans exist or are being developed, for example, the 2012–2016 Lokok catchment plan. We propose supporting the capacity of watershed management organizations to include land use and trees in their planning activities. There is inadequate recognition of indigenous norms, practices and cultures in statutory rules in water use and management, yet they take precedence over statutory rules. We do

60 http://opm.go.ug/departments/management-of-special-programmes/northern-uganda-data-center-nudc1.html

not know the range of indigenous practices and norms regarding water use and management, or the lessons we can get from these. This mainstreaming of trees might include:

a. **Trees for flash flood control**. Flash floods are common in the Karamoja sub-region, destroying lives and property. Trees and ground covering vegetation significantly reduce run off and the occurrence of flash floods. We propose to develop an agenda that supports a higher cover of trees in crop fields and rangelands.

b. **Trees for erosion control and waterway fixation**. Barren lands result in erosion washing away valuable soils and silting up streams and rivers and dams. Similarly, high volatility of water discharged by various waterways leads to regular erosion of their banks, with negative effects of livelihoods depending on these systems. Leaving these losses unaddressed has economic consequences. We propose to support a tree-based agenda to reduce the filling up of reservoirs and degradation of waterways by land degradation-related erosion.

c. **Trees for resilient crop production**. The productivity of the landscapes that support Karamojong livelihoods is affected by drought-related water scarcity. The promotion of croplands without trees intensifies this vulnerability while, in contrast, the inclusion of trees has the potential to alleviate the adversity of these weather anomalies. We propose developing a policy and associated interventions that promote the establishment of a minimum cover of trees in croplands.

d. **Trees for resilient livestock production**. Livestock production in Karamoja is sensitive to drought when the supply of forage dwindles. This is particularly so in landscapes without trees. Due to their access to deep water resources, trees remain green during longer periods than non woody species. Because of this, trees have the potential to provide forage during the dry season thus reducing the scarcity of feed. We propose an agenda to promote the establishment of forage trees in rangelands.