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Unsafe Havens: The Meaning and Use of Springs in the Central Region of Afar Province in Ethiopia

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Abstract: Background: We explore how springs and their pastures are utilised by nomadic pastoralists and how they influence interchange and conflict between the custodians of the springs and the society of pastoralists in the broader region. Methods: The custodians of three spring locations in the Afar region of Ethiopia were interviewed to identify the advantages, and the challenges, of having springs on a pastoral estate. Results: The springs provide permanent water and health benefits, are used for cooking, and provide permanent pasture for livestock. In the Dobi Valley, the groundwater supporting the springs supports a population of the palm *garayto* (*Hyphaene thebaica*), which provides thatch and a liquor derived from the sap. The custodians of the springs are *baaro-mara* for their homelands and they welcome and provide access to the resources of the spring to Afar outsiders, *gurro-mara*. Recent invasions by the Somali Issa tribe have resulted in the deaths and displacement of Afar residents at Alalo-bad and Teo. The prickly shrub *Prosopis juliflora* has become another invasive threat with great impacts on the livelihood of the *baaro-mara* at two locations. Conclusions: Springs are oases where permanent water provides perennial resources in a semi-desert. However, the tenure of these precious havens can be subject to tribal contest and the resources of the springs have been recently undermined by invasion of a plant from another continent. The removal of the incipient population of *Prosopis juliflora* should be a priority before it proliferates further.

Keywords: Afar; Ethiopia; invasive; nomadic pastoralist; *Prosopis*; springs

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1. Introduction

Springs provide a critical resource for humans in desert and semi-desert landscapes, but the nature of their dependency has only rarely been described. In North Africa, springs provide for oasis settlements with agricultural production dominated by date palms [1]. In these settings, there are sophisticated water systems directing the water from the spring or other groundwater sources to the plantations through a network of streams [2,3]. Nomadic pastoralism is another human adaptation to arid environments. Nomadic pastoralists have refined access to water and forage under ephemeral seasonal conditions by moving across large tracts of land [4].

Springs provide a rare but perennial resource in arid environments and must also be a critical resource for nomadic pastoralists. Here, we report on interviews with nomadic pastoralists in the central Afar region of Ethiopia (Figure 1). We commence with a brief

overview of the lifestyle of the Afar nomadic pastoralists and how they manage in a harsh desert landscape prone to drought. We shift the focus to three spring complexes and describe their physical environment. We also present information on the chemistry and temperature of the springs, most of which are hot at their source. The plants and fish associated with the springs are identified and their importance for fodder and other uses, as well as their significance for regional biodiversity are determined. We then explore the importance of the springs for the people and whether the permanence of the springs as a water source results in a more sedentary existence. We identify the advantages, and the challenges, of having springs and the drought-proof pastures they support. We provide some detail on how the presence of a spring on a pastoral estate influences interchange and conflict between the custodians and the society of pastoralists in the broader region. There are long-standing enmities between the Afar and the Somali tribe Issa and the impact of this conflict at the three spring locations will be revealed and discussed.

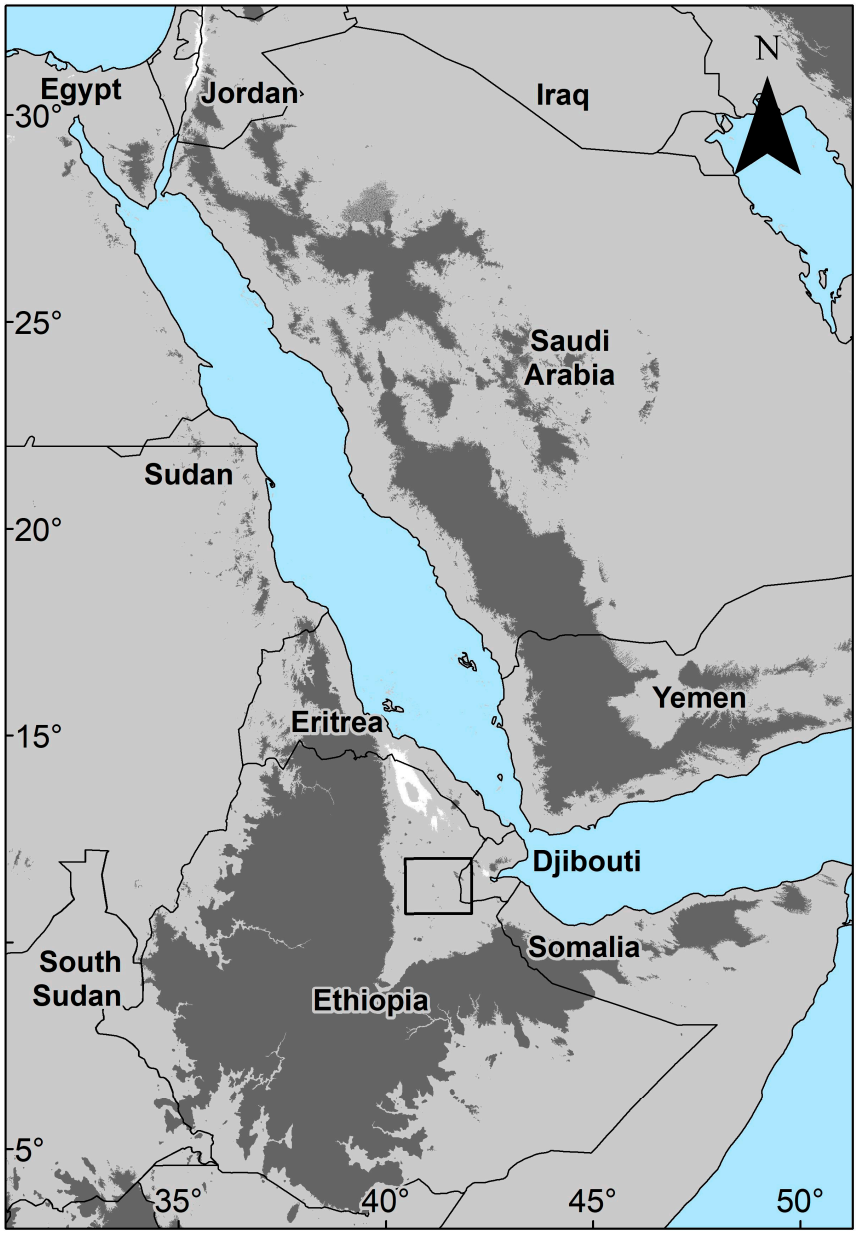


Figure 1. A map of Ethiopia and the regional context of the Afar region. The tones relate to elevation, where <0 m—white; 0–1000 m—light grey; and >1000 m—dark grey. The Afar is the triangle-shaped region around the rectangle, which is the study area depicted in Figure 2a.

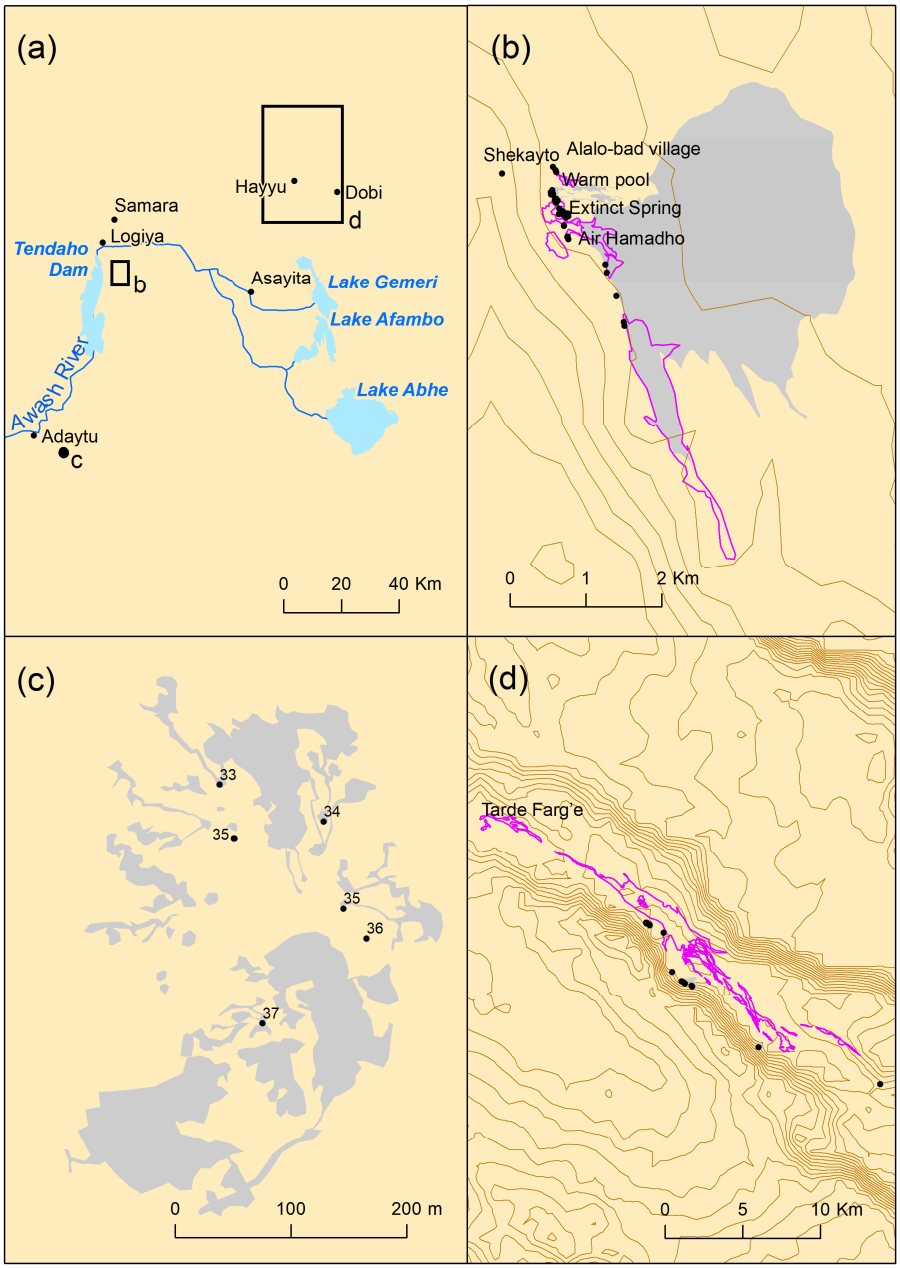


Figure 2. The region of the three study locations (**a**) in Afar province, Ethiopia (Figure 1): Alalo-bad (**b**), Teo (**c**), and Dobi Valley (**d**). The wetlands formed by the springs are depicted in grey; *Prosopis juliflora* infestations are depicted by the pink polygon. Springs numbered and with associated chemistry or temperature data are represented as black dots and the associated data are included in Table S1.

Spring ecosystems can be vulnerable to invasive plant species [5,6]. *Prosopis juliflora* has probably been present in Ethiopia since the 1970s [7]. Since then, it has become one of the most problematic invasive species in semi-arid regions in the Horn of Africa, with a substantial impact on the livelihood of pastoralists [8,9]. In the Afar, it is advancing at a rate of 50,000 ha per annum [10]. The species displaces pasture, harbours predators, and hinders the movement of livestock and pastoralists; the thorns make people blind and lame, and the leaves are inedible because of their tannin content [7]; it causes tooth decay in goats [9], and people and animals can be allergic to the pollen [11]. The current study will assess the impact of *Prosopis juliflora* on the environments of the springs and the livelihoods of the pastoralists and provide recommendations for quarantine and control.

2. Materials and Methods

The information presented in this paper was developed from field work during February–March 2024. The lead author Fensham and second author Bil'a, who is fluent in the Afar language, interviewed local pastoralists and other informants. Conversations focused on the following:

1. The resources and values of the springs.
2. How the spring environments have changed and are managed.
3. How local people accommodate visitors and how they have been affected by unwelcome invaders.
4. The history of invasion by *Prosopis juliflora* and the positive and negative impacts of its invasion.

Information was checked and verified by subsequent phone conversations. The information is specific to the region and people and may vary from other published sources on Afar nomadic pastoralism [12,13]. There are no women on the authorship team and women were not directly interviewed for this project. It is recognised that the specific importance of springs for women is not canvassed by this study.

The springs and their associated wetlands and the infestations of *Prosopis juliflora* were mapped using Sentinel Imagery (March 2024, 10 m pixel, 3 band with near-infrared) and World Imagery (June 2017, 0.5 m pixel, 3 band without near-infrared) (Figure 2a–d).

An unpublished historical report [14] provided important geological, geochemical, and historical information about the springs. The locations of the sites in this report and the chemistry data have been geo-rectified and are reproduced here. They are supplemented with some measurement of temperature, pH, and electrical conductivity (Table S1). The locations referred to in the text are represented in Figure 2 and are geo-referenced in Table S1.

3. Results

3.1. The 'Afar Triangle' and the Central Region of the Afar Province

In terms of climate, geology and culture, the 'Afar triangle' is a distinct geographic region (Figure 1). The region is partly independent from the African, Arabian, and Somali plates that adjoin its three sides [15,16]. The Red Sea represents the separation of two continental masses as the Arabian plate moves northwards more rapidly than the African plate. The coastlines of the two land masses fit almost perfectly, except the Afar triangle, which can be superimposed under the upland region of Yemen, Bab el Mandeb (Figure 1). The jigsaw would be precise if Afar were on the sea floor. In fact, Afar is low-lying, with some areas below sea level (Figure 1) and few areas above 1000 m compared to Bab el Mandeb (Figure 1). Because of the tensions associated with tectonic rifting, the region has elevated volcanic and seismic activity [15]. Igneous basalt is the dominant geology and active volcanoes are prominent in the northern Afar [15]. The central Afar is dominated by Pliocene–Pleistocene basalt flows that are extensively rifted, and in some areas grabens form broad flat-bottomed valleys [15], including the valleys containing the spring complexes described here. Associated with the seismic activity are thermal springs heated by bodies of magma, about 500–1500 m deep and discharging through faults [17].

The 'Afar triangle' (Figure 1) straddles Ethiopia, Eritrea, and Djibouti, and the Afar people, defined by the Afar language, are present in all these nations, although most dominant in Ethiopia, where they mostly occupy the province of Afar. The central region of Afar province includes the original capital Asayita (previously Aissa) and the new capital Samara (Figure 2). The major perennial stream in the region is the Awash River, which flows from the highlands of central Ethiopia down the Rift Valley and on to the broad flood-plain of central Afar. Its drainage terminates in a vast system of lakes about 100 km from the Red Sea (Figure 2).

The climate of central Afar is semi-arid, with 328 mm mean annual precipitation at Samara, with an unreliable wet season between July and September, *karma*, and a more modest and even less reliable peak in rainfall during March and April, *suggum*. October to

February is the cool dry season *gillal*. May–June is the hot dry season, *haggay*. Mean monthly maximum temperature reaches 41 °C in June but is never below 34 °C. Mean monthly minimum temperatures range between 19 °C during *sugum* and 28 °C during *haggay*.

3.2. The Afar Nomadic Pastoralists

The livelihood of the Afar pastoralists is critically dependent on the shifting availability of water and forage resources. Their animal herds are typically mixtures of cattle, goats, sheep, camels, and donkeys, and their forage resources are the herbage of grasslands available after rain and the fodder provided by trees and shrubs that are more heavily utilised when herbage has declined. Water is available from the Awash River but also rarely from *boi'na*, excavated wells. The availability of water in wells and fodder from herbage are highly variable in time and space. There are also government-supported water delivery services for some pastoralists.

There are traditional governance structures that determine access to the shifting resources. The people are organised into clan groups, for which *baaro-mara* are the primary residents of a domain of land with a reliable water source. The *baaro-mara* enjoy ancestral and communal rights to their estate but are also obliged to share with neighbouring groups, *gurro-mara*. The *baaro-mara* welcome the *gurro-mara,* recognising their needs and the importance of the reciprocal arrangement. If the resources of the *baaro-mara* become depleted, then they will become *gurro-mara* to use the resources of other *baaro-mara*. If the visiting pastoralists are not Afar, they may also be accommodated providing there is no history of animosity.

If there are unresolved past hostilities, the visitors will be regarded as intruders and the resources of the *baaro-mara* will not be shared until the ledger of conflict is resolved. These disputes can result in serious clashes, including loss of life, destruction of property, and the take-over of traditional homelands.

3.3. Afar–Issa Conflict

The Afar and the Issa, the Somali tribe to the south, have a long history of conflict. They occupy the Afar and Somali provinces of Ethiopia, where their Islamic religion is a point of distinction from other ethnic groups, who are predominantly Orthodox Christian. The Afar language and culture relate to the distinctive lowland, semi-arid geography of the Afar triangle, which straddles three nation states, Ethiopia, Eritrea, and Djibouti (Figure 1). The Issa straddle two nation states, Ethiopia and Somalia.

Enmities between the Afar and Issa are ancient and have an origin in myths relating to inheritance and treachery in the first family of humanity [18]. These entrenched cultural animosities seem to be a prevailing motivation for disputes, over and above the resource constraints given the *baaro-mara–gurro-mara* tradition.

There have been recent political aspirations from these groups for a Greater Afar and Greater Somalia homeland. The Somali and Afar provinces are remote, culturally isolated, and difficult to manage by the central Ethiopian government. It has been suggested that conflicts between the Issa and Afar provide a convenient distraction from aspirations of sovereignty that have the potential to undermine the borders of three nation states in the Horn of Africa [18]. In recent years, recurrent disputes over contested districts along the Afar–Somali provincial boundary have escalated into violent battles. While the Issa–Somali communities have sought the integration of Afar into the Somali Region, the Afar authorities firmly assert their jurisdiction over these areas. These territorial disagreements have resulted in recurring clashes and widespread displacement of local populations. Conflicts are more dangerous than ever with the widespread possession of automatic weapons.

3.4. Alalo-Bad

The Alalo-bad springs arise from a north–north-west fault that is downthrown to the east, forming the western flank of the broad Tendaho Graben [14]. The flanks of the graben are flood basalts of Plio-Pleistocene age.

The *baaro-mara* at Allalobad consists of about 120 people, although additional people live in the nearby town of Logiya. About 80 of the residents are children under 16 years of age. The village is an area of elevated ground about 500 m north of the main spring and consists of about 20 *Afar ari*, the traditional dwellings of the Afar (Figure 3). The thirty springs mapped at Alalo-bad (Figure 2, Table S1) are all extremely hot, and measured temperatures are between 58 °C and 100 °C but can be difficult to obtain from the core of discharge, where most are probably near boiling point. Thus, the water must drain and be cooled before it can be used for washing or drinking. Three large springs in the north of the complex (Table S1 4, 11, 5) are cone-shaped depressions, 30–40 m in diameter, that are seething cauldrons of steam and boiling water. The springs are encrusted with travertine which also forms platforms surrounding the springs. The specific name for the habitat around the springs is referred to as *Addo-bad* referring to the white areas of travertine.



Figure 3. Typical dwelling place for pastoral nomads in Afar. The domed *Afar ari* is a common dwelling, with animal pens fashioned from *woyane*.

About 700 m west of the village on the side of the mountain range is an important location known as Shekayto (Figures 2b and 4). This site gathers water from steaming vents at higher elevation and is shaded under two *subla* trees (fig; *Ficus sycomorus*). This water is favoured for drinking and is only used for this purpose. The conductivity of this spring is 0.076 mS, indicating a low salt content (Table S1). This contrasts with the other springs, with a conductivity from 0.013 to 4.00 mS. There are ribbons tied in the trees, a past practice of offering to ensure that the quality and quantity of the spring continues.



Figure 4. Shekayto. Under the shade of these fig trees, water from steaming fumaroles gathers and is a favoured spot for drinking water.

The main springs at Alalo-bad on the flat below Shekayto are moderately alkaline (pH 7.3–9.3), have moderate conductivity (0.013–4.00 mS), moderate concentrations of sodium (500–595 ppm), chloride (603–760 ppm), and sulphate (209–334 ppm (Table S1). Thus, the water is potable but mineralized. Salt (sodium chloride) precipitates around the edge of the springs as the slightly brackish groundwater evaporates.

The northernmost large spring (Table S1 4) is considered to be the main spring and drains into a second spring (Table S1 8) and then through 50 m of excavated drain to a large warm pool (9, Figure 5). The water in this pool has cooled to 40 °C and is intensively utilised (Figure 5). This warm pool is the main place for body washing, clothes washing, and for watering livestock, and it is also used for drinking. The spring water is very important for human and animal health. The drinking of the water by humans and animals is regarded to cleanse the stomach, aid digestion, and alleviate haemorrhagic disease. The livestock of the *gurro-mara* may be reluctant to drink the brackish water at Alalo-bad but become accustomed in a few days, in the same way that the animals from Alalo-bad need to become familiar with river water when they are taken away. The drinking of spring water can alleviate the syndrome of swollen mouth in livestock caused by some forage such as the pods of *woyane* (see below).



Figure 5. Outflow from the main spring at Alalo-bad (where the steam is rising in the background). This is the warm pool (Table S1 9) where livestock water (top) and for bathing and washing (below).

The steam from the main spring (Table S1 4) and the two middle springs (Table S1 12, 15) (Figure 6) is also excellent for health and travellers come especially for treatment. Breathing the steam provides benefits for the lungs and exposing the body to the steam provides benefits for the skin. Exposure to the steam also relaxes tension in the body. After spending two or three days exposed to the steam, people who are affected by arthritis will be relieved.



Figure 6. The steam on the body of the main springs at Alalo-bad is therapeutic. The photo represents spring 12.

Animals with parasites or skin problems are dragged into the water of the warm pool and washed. The steaming springs are also beneficial for livestock, as they are for humans, and animals can be held in the steam and then plunged into the warm pool for a double treatment.

To the south of the main spring are two steaming, small bubbling mud puddles (Table S1 11) only two metres apart. The southern one is known as *ballo* (mother-in-law) and the northern *ballu* (father-in-law) (Figure 7). The hot mud from these springs is scooped from the spring with the help of a long stick and poured on to a rock to cool. Once cool, it can be applied to the face and body, and treats skin diseases, such as scabies and boils, and muscle ache, as well as being a balm for general body health.

Towards the south of the complex are the cooking springs in the area, known as Air Hamadho (Figure 8). The lower and larger spring has multiple bubbling vents (Table S1 25, 26) that are used for boiling sorghum, maize, and diced meat and can be used to make tea and coffee. Above this spring is a steaming vent (Table S1 27) that is used for cooking larger portions of meat. Around the springs are deposits of salt that are well-regarded for culinary purposes (Figure 6).

There are springs and fumaroles about 1 km to the south (Table S1 28, 29, 30), and these have been approximately mapped by the United Nations Development Programme [14] but have become infested by *woyane* (*Prosopis juliflora*), were not visited in 2024, and are no longer important for people.



Figure 7. *Ballo* (left) and *ballu* (right), two adjacent hot mud springs where mud is extracted with a scoop on a long pole and the mud is used on the skin.



Figure 8. Air Hamadho, the cooking springs at Alalo-bad. The steaming spring (rear on the slope, Table S1 27) and the boiling spring (mid-ground, 25, 26). Salt precipitates around the springs and is gathered for garnish.

Once the outflow of the water has cooled to about 60 °C, it forms wetlands dominated by *dara*, a short sedge, *Cyperus laevigatus*. *Dara* only grows on springs and thus is a unique form of forage that persists through droughts. It is regarded as a nutritious forage but occurs only on limited areas near the springs themselves relative to the total wetland area (Table 1). The springs discharge beyond the *dara* wetlands into an extensive wedge-shaped wetland (Figure 2b) referred to as *data-bad* (Figure 9). The *data-bad* is dominated by *gadeyta* (bull-rush, *Typha latifolia*), *hamilto* or *eyayto* (short reed, *Phragmites australis*), and *dangalto* (tall reed, *Phragmites karka*), as well as a less conspicuous plant (*Bolboschoenus maritimus*). *Gadeyta* is used to make a mattress and with *hamilto* and *dangalto* is used as thatch for temporary shelters. The stems of *dangalto* can also be used to make a *forrima* (clarinet-like instrument). The *data-bad* is a perennial pasture but the water level in this wetland expands and contracts depending on evaporation and seasonal conditions. The deep mud in the interior of the wetland is hazardous for livestock because they get stuck and can perish. The edges of this wetland are suitable for grazing but cattle and camels are more adept at avoiding bogging than sheep, goats, or camels. Local animals are more adept at avoiding this fate than the livestock of the *gurro-mara.*

Table 1. Wetland area and *woyane* (*Prosopis juliflora*) infestation at the three locations.

Location	Wetland Area (ha)	*Prosopis juliflora* Infestation (ha)
Alalo-bad	981	101
Teo	4	0
Dobi Valley	13	1235



Figure 9. View over the *data-bad* (vegetated wetland) on the outflow of the springs at Alalo-bad. Thickets of *Prosopis juliflora* are evident in the mid-ground. The *data-bad* is in the background and the light green is produced by the flowering heads of *hamilto* or *eyayto* (short reed, *Phragmites australis*) and *dangalto* (tall reed, *Phragmites karka*).

The people at Alalo-bad relate changes in the springs to the influence of the impoundment of the Awash River by the Tendaho Dam, constructed in 2014 (Figure 2a). Prior to the building of the dam, the springs were considerably more violent, with exploding and erratic jets of steam (Figure 10). In general, the outflow from the springs was less. In these

times, jets of water were visible from Logiya, 9 km distant. It was not safe to be near some of the springs and people avoided coming too close for fear of being scalded by a jet of steam.



Figure 10. Photo reproduced from United Nations Development Programme [14] with caption: 'Continuous spouter at Allallobeda hydrothermal area. Pulsating water jets erupted up to 6 m high. Scarp of Loggia Fault in rear (E.F. Lloyd photo November 1970)'. The photo is spring 4.

With the advent of the Tendaho Dam, the water levels in the Awash have been maintained at high levels and the springs are less violent and are flowing more, and new springs have emerged. The locals' interpretation is that the water has infiltrated from the dam under the basalt mountain range and into the aquifer of the spring. In 1970, a tribesman estimated at less than 60 years old recalled that when he was a boy, this spring had a higher water level and was a placid pool [14]. If this account is correct, then fluctuations in the force of spring discharge may occur over long timescales and independently of the dam. There is at least one extinct spring at Alalo-bad (Figure 2b, Table S1), although the event occurred in the distant past and does not have a story.

Woyane (mesquite, *Prosopis juliflora*) infestations cover about 100 ha (Figure 2, Table 1) and have become a serious problem at Alalo-bad. The plant forms tangled thickets (Figures 9 and 11) and is adorned with abundant sharp thorns and can be useful for making animal pens (Figure 3). *Prosopis* has proliferated in low-lying areas at Alalo-bad since 2009 and replaces important pasture and is almost useless as forage. *Prosopis* thickets harbour hyena which predate livestock and hinder the movement of livestock and people. The pods are useful as forage for goats but cause swollen mouth in other livestock. Overconsumption by goats causes constipation. It proliferates in the low-lying areas around the springs and is abetted by the outflow from the springs. In places, the local people have built bunds to restrict the outflow from the springs in order to limit the growth of *woyane.*

The people at Alalo-bad have been resident for generations and are the rightful *baaro-mara.* However, they have not had continuous possession. In 2008, *Issa* people from the south invaded and displaced the local people until 2022. Ten people were killed in the conflict. The people killed in battle by another clan are lain on the ground and covered by

a monument of rocks (*waydal*; Figure 12). This marks the memory of the killing, and the body is not exhumed and properly buried until retribution is complete.



Figure 11. Woyane (*Prosopis juliflora*) thickets (background) with *dara* (*Cyperus laevigatus*) pasture (foreground) at Alalo-bad.



Figure 12. *Waydal* temporary tombs for those killed in battle requiring revenge.

3.5. Teo

The Teo springs (Figure 2c) lie in the Teo Graben, which forms a flat-bottomed, north–south valley about 900 m wide bounded by low basalt mountain ranges. The springs emerge towards the eastern escarpment and emerge from the downthrown side of a north-west trending fault [14]. The word *Teo* refers to something coming up from the ground, and there are more than 100 springs clustered within an area of 10 ha. The springs emanate from an area encrusted with travertine (Figure 13). The highest springs are about 2 m above the lower springs. Two small 13 m and 10 m round springs about 10 m apart are at the highest elevation. The water from these is boiling and steaming vents are used for cooking meat. These hot springs discharge along excavated drains (Figure 14). There are many other springs at lower elevations that have slightly lower temperatures (Table S1), and also sub-surface flow that allows for extraction of cooler water (~40 °C) from excavated vertical holes for drinking. The warm water also drains into pools that are used for washing. Many of the springs and pools are joined by an extensive network of excavated drains. Some of the springs are bubbling mud as occurs at Alalo-bad, and the mud enhances the flow of milk when rubbed on the udders of livestock and the breasts of women. The springs are slightly more acid than the waters at Alalo-bad and Dobi but have similar levels of sodium, chloride, and sulphate (Table S1).



Figure 13. People and livestock around the springs at Teo. Travertine precipitated from the groundwater forms the white rock. *Dara* (*Cyperus laevigatus*) forms the short pasture and *gadeyta* (*Typha latifolia*) the tall thickets in the background. *Woyane* (*Prosopis juliflora*) are only occasional, not having proliferated as at Alalo-bad and Dobi Valley.



Figure 14. Boiling spring at Teo with excavated channels (lat: 11.0690; long: 40.8513).

Dara dominates wetland areas fed by the springs and forms a pasture over about 4 ha (Table 1) amongst the travertine pavement. The grass *antarba* (couch, *Cynodon dactylon*) also provides important forage. There are also clumps of *gadeyta* and the occasional patches of *hamelto*. *Prosopis juliflora* was present but had not yet proliferated.

There were violent battles around 1974 between the Afar and Issa people who had moved into the area from the south. During these battles, the national government lost control; many people were killed and the nearby town of Adaytu was destroyed. The national government regained control about 2016 and formed the new district of Kilalu, with security forces, road development, and reconstruction in attempt to stabilise the region. During these troubles, the local people were displaced from Teo for more than a generation (~1976–2016), resulting in a loss of association with the springs. The returning newcomers were Aloma people from the east and Harisimela from the west. The two pastoral groups utilise their own territories but reside together at the spring. They graze cattle, goats, sheep, camels, and donkeys at the springs. The newcomers have the rights of their ancestors and are considered *baaro-mara*. During our visit, it was difficult to gain precise and detailed information because of their fragmented past, but about 200 people with large herds of livestock seemed to be enjoying a peaceful coexistence around the secure resources of the springs. Adaytu has been rebuilt and there is a new road to Teo. There are also about 30 government-built houses at Teo, although they do not seem to be occupied by the local people, who prefer the traditional and cooler *Afar ari*.

3.6. Dobi

The Dobi Graben forms a flat-bottomed valley orientated south-east and draining from the north-west. It is bordered by mountain ranges that rise about 500 m above the valley (Figures 2c and 15). At the bottom of the valley are saltworks around the settlement of Dobi and the springs are towards the top of the valley. There is shallow groundwater throughout the valley which can be accessed by shallow wells.



Figure 15. Goats in the flat-bottomed Dobi valley feeding on *dara* (*Cyperus laevigatus*) pasture on shallow groundwater at Lahidu (52). *Garayto/Unga* (*Hyphaene thebaica*) trees in the mid-ground are surrounded by young plants which are harvested for thatch.

There are four spring clusters in the Dobi Valley about 10.5 km apart (Figure 2d). Lahidu (52) emanates from the southern side of the valley and has relatively cold water (36 °C). It has the most modest flow but supports an area of *dara* pasture (Figure 15). Kio, about 6 km upstream from Lahidu, has springs spanning 500 m apart, also on the southern side of the valley. The lowest is Big Kio (46–51) and the upper is Little Kio (45). The waters of big Kio (49 °C) are cooler than Little Kio (57 °C). Darayto (Figure 16; 44) is about 4 km further up the valley and has several vents with a temperature of about 48 °C. Gunguna (38–43) is about 0.5 km above Darayto. Gunguna has about 12 vents with temperatures between 36 °C and 40 °C that run down excavated drains to wetland pasture. About 0.5 km east of Darayto is a perennial stream called Bagili-farg'e that has its source at hot springs called Tarde farg'e about 14 km further up the valley (Figure 2d).



Figure 16. Dorayto spring (44) in the Dobi Valley. Young *garayto* (*Hyphaene thebaica*) form thickets around the spring with the tangled form of *woyane* (*Prosopis juliflora*).

A distinctive feature of the Dobi Valley is the abundance of the palm *garayto* (also *unga-harra*, *Hyphaene thebaica*). The Dobi Valley is underlain by a watertable less than 2 m below the surface and is tapped by shallow wells. The palm is able to tap this shallow water table and proliferates throughout the valley in places without springs. Young *garayto* provides thatch that is cut extensively by the people in Dobi for export where it is woven to *dibora* for roofing of the Afar ari, walls, mats, and decorative hangings. Soaking the thatch in water preserves the fibre and makes it flexible and the springs are used for this purpose. The sap (*doma*) (Figure 17) from *garayto* is fermented and drunk to provide extra energy for an arduous task, such as walking the high mountain pass to Hayyu. It can be drunk straight or diluted with water, but mixing the two recipes will induce a drunken state. The sweet pulp surrounding the nuts (*ailla*) (Figure 17) is eaten. The nuts also provide fodder for livestock. *Ailla* ripen during *sugum*.



Figure 17. Harvesting the *doma*, the sap of *garayto* (*Hyphaene thebaica*) (top), and *ailla*, the nuts (bottom) which have a sweet pulp when the hard case is removed.

The pasture in the immediate outflow from the springs is dominated by *dara* but includes other species that are not present at Alalo-bad and Teo. On the wetlands, with *dara*, is *dodoba* (either or both of two salt tolerant grasses, *Paspalum vaginatum*, *Aeluropus lagopoides*), *fi'a* (*Fimbristylis ferruginea*), and *Eloecharis geniculata*,which is similar to *dara* and was not distinguished by our informant. Extending from the wetlands into drier areas is *antakar* (salt couch, *Sporobolus virginicus*). The outflow from the springs supports areas of *gadeyta* and *hamilto.* The invasion of *woyane* has occurred in the last 20 years and is now extensive in the Dobi Valley (Figure 18). The infestations are particularly severe around the springs and have overtaken more than 1200 ha (Figure 2d, Table 1), the vast majority of the area around the Kio, Darayto, and Gunguna (Figure 2d). The locals understand that *Prosopis* is dispersed through animal dung. Thickets have contracted the productive

pasture of *dara*, *antakar*, *dodoba*, and *fi'a* and the tall pastures of *gadeyta* and *dangalto*. They have also outcompeted *garayto*.



Figure 18. Impenetrable *Prosopis juliflora* infestations have taken over large areas in the Dobi Valley (Figure 2d).

There are about ten households associated with Kio and about twenty-five at Darayto, but the people represent a single *baaro-mara*. The springs are much smaller than Alalo-bad but are used in a similar way for washing, drinking, and for health purposes. Mud springs are available for a skin balm. The springs are cooler than the other two locations (less than 70 °C at the vent), while the water chemistry of the springs at Dobi is similar to that at Alalo-bad: moderately alkaline, with moderate conductivity and moderate concentrations of sodium, chloride, and sulphate (Table S1).

Small 30 mm fish were present in the warm ponds (<40 °C) of the outflow and were identified as a species of killifish (*Aphanius* sp.). Dobi Valley is 170 km from the nearest known populations of *Aphanius* in the springs near Lake Afdera [19,20].

The valley is prone to floods which inundate the springs up to 4 m depth, and during these times, the people move to higher rocky ground. Fifteen camels were lost in the flood of the rainy season in 2023. They welcome *gurro-mara* according to Afar tradition, including non-Afar people who use the valley to cut and burn *woyane* for charcoal. Unfortunately, however, it was *gurro-mara* and their livestock that brought *woyane* to Dobi Valley. The people of the Dobi Valley have been there for generations and have not been invaded or threatened by invaders in recent times. The invasion has occurred from *woyane* where impenetrable spiny thickets are much more expansive than at Alalo-bad or Teo.

4. Discussion

The springs are a vital resource for the people who live in the semi-desert landscapes at Alalo-bad, Teo, and the Dobi Valley. They provide water for drinking and washing and are important for digestive and skin health. They also provide water for drinking and for the skin health of livestock. The mud has special properties for skin health, and the steam alleviates respiratory, muscle, and joint conditions. The hot springs are also used for cooking.

The outflow from the springs provides perennial pasture, including specialised 'spring pastures' dominated by *dara* (*Cyperus laevigatus*) in the areas close to the discharge and further out the tall pastures of *gadeyta* (bull-rush, *Typha latifolia*) and *hamilto* (*Phragmites australis*). The springs are potable but deposits of salt accumulate around the outflow through evaporation. Thus, many of the plants forming productive perennial pasture around the springs (*Bolboschoenus maritimus*, *Cyperus laevigatus*, *Eleocharis geniculata Fimbristylis ferruginea*, *Paspalum vaginatum*, *Sporobolus virginicus*) are also found in saline coastal environments. Prior to our surveys, many of these species had not previously been recorded in the Afar region [21]. The groundwater that feeds the springs in the Dobi Valley also provides habitat for the palm *garayto* (*Hyphaene thebaica*). *Garayto* is a critical resource here and elsewhere in North Africa, where it is used for thatch, food, and for an alcoholic drink made from the sap [22].

The permanence of the springs ensures that the surrounding pastures are productive when the broader landscape is denuded by drought. For the nomadic pastoralists without springs, these are the most difficult times for humans and their livestock alike [13]. During these periods, the springs provide an essential water source and pasture reserve for visiting *gurro-mara* who are normally welcomed.

The springs are a godsend for the *baaro-murra* but are also desired by tribal nomads who have long-standing animosity with the Afar. The rivalry is ongoing and during recent times, the *baaro-marra* of the springs at Alalo-bad and Teo have been killed and displaced by the *Issa*. Killings can be compensated by 'blood-compensation' payments, usually with livestock [23], but the entrenched nature of the animosity between the Afar and Issa and the 'blood-debt' from the recent conflicts have not been resolved.

The waters from springs also create an environment conducive to another invader. *Prosopis juliflora* displaces pasture, harbours predators (principally hyena in Afar), and hinders the movement of livestock and pastoralists. *Prosopis juliflora* has some benefits. It is used to make animal pens, the ripe beans are nutritious providing they are not overused [24], and an industry has been developed from the cutting and burning of mesquite for charcoal. *Prosopis* was present in the district of Alalo-bad in the early 2000s, but was not recorded in the Dobi Valley region [7]. The infestations are extensive in the Dobi Valley (1235 ha), moderately extensive at Alalo-bad (101 ha), and although present at Teo, *Prosopis* has not yet formed thickets. The observation of people that *Prosopis juliflora* is dispersed through animal dung, particularly cattle, is verified by experiment [25,26]. It is only in the last 20 years that its proliferation has severely compromised the habitat around the springs.

5. Conclusions

Springs are oases where permanent water provides perennial resources in a semi-desert [27]. They are also important locations for biodiversity [28], and the Afar springs are no exception, with isolated populations of plants and fish. However, these havens are places where tenure is disputed during violent battles. The resolution of long-standing enmity between the Afar and Issa seems intractable but should recognise the discrete geography of the Afar territory (Figure 1). Resolution may require negotiated settlement beyond retribution for individual deaths or past battles.

The fertility of the habitat around the springs have also provided the condition for another invasion, the thorny shrub *Prosopis juliflora*. The removal of *Prosopis* from the springs is achievable with a concerted campaign that could incorporate learnings from other countries such as Australia, where other woody legumes have been invasive and

effectively controlled in spring environments (R. Fensham pers. obs.). Applying herbicide to cut bark or stumps is an effective method for removing *Prosopis* [29] and follow-up hand pulling of seedlings is necessary to deplete the seedbank [30]. Further assessment of other spring locations would provide context and highlight priorities. An information exchange between pastoralists impacted by severe invasion of *Prosopis* and those where pastures are intact, but threatened by *Prosopis*, should motivate the eradication of incipient populations and subsequent quarantine. This information exchange is particularly relevant at Teo, where the eradication of *Prosopis* requires small effort to preserve the spring wetland pastures. Quarantine and management to remove *Prosopis* and restore the natural spring environments, including key biodiversity assets, could be efficiently achieved with financial support and delivered by a local authority such as Afar Pastoralist Development Association (APDA; www.apda-ethiopia.org accessed on 12 August 2024).

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/w16243698/s1: Table S1: Spreadsheet with spring numbers, locations, and water temperature and chemistry.

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