Managing variability and scarcity. An analysis of Engaruka: a Maasai smallholder irrigation farming community

Martina Angela Caretta

Human Geography Department – Stockholm University

Svante Arrhenius Väg 8, 10691, Stockholm University, Stockholm, Sweden

Email: martina@humangeo.su.se

Phone: +46 70 534 21 15

Fax: + 46 08-16 49 69

Abstract

This article examines the common-pool regime of Engaruka, a smallholder irrigation farming community in northern Tanzania. Irrigation is a complex issue due to water asymmetry. Water use is regulated in Engaruka through boundary, allocation, input and penalty rules by a users´ association that controls and negotiates water allocation to avoid conflicts among headenders and tailenders. As different crops – maize and beans, bananas and vegetables- are cultivated, different watering schemes are applied depending on the water requirements of every single crop. Farmers benefit from different irrigation schedules and from different soil characteristics through having their plots both downstream and upstream. In fact, depending on water supply, cultivation is resourcefully extended and retracted. Engaruka is an ethnically homogeneous and interdependent community where headenders and tailenders are often the same people and are hence inhibited to carry out unilateral action. Drawing on common-pool resource literature, this study argues that in a context of population pressure alongside limited and fluctuating water availability, non-equilibrium behavior, consisting in negotiating water rights and modifying irrigation area continuously through demand management, is crucial for the satisfaction of basic and productive needs and for the avoidance of water conflicts.

Highlights:

- Water management in Engaruka is a common-pool regime
- The mgawa maji controls water distribution and avoids conflict
- Population pressure and fluctuating water supply lead to non- equilibrium behavior
- Non-equilibrium behavior requires water demand management
- Rights to agricultural expansion are constantly negotiated

Keywords: smallholder farming, canal irrigation, common-pool regimes, non-equilibrium behavior, Tanzania

1. Introduction

Governance and management of limited and fluctuating water supply is a fundamental challenge facing many irrigation systems. Water allocation in such a context can generate conflict, especially when the irrigation system is the most important source of livelihood for the local community (Tang, 1992). These circumstances are further strained when population pressure increases demand for an already limited resource. In studies of common-pool resources there is consensus that small homogenous local groups can bring about successful institutional arrangements that can ensure the sustainable use of resources. However, dealing with a resource such as irrigation water, is a challenge even for the most resilient local institutions as it is mobile, variable, inherently asymmetric and tends to be in control of headenders. (Komakech et al., 2012; Lein and Tagseth, 2009; Agrawal, 2001).

Often the degree of water scarcity affects the rules, and their stringency, around water use (Tang, 1992). Free-riding becomes more common when pressure on the resource augments. In common property regimes there is no individual ownership over the resource at stake, but membership and benefits are harnessed through the fulfillment of certain obligations such as construction and maintenance of the irrigation infrastructures (Lein and Tagseth, 2009; Sokile and van Koppen, 2004; Boelens and Davila, 1998; Ostrom and Gardner, 1993). Cooperative water allocation is not a given (Lankford and Beale, 2007). However, irregular water supply generates an incentive to collaboration so that every shareholder will be granted a sufficient amount of water. While this might be especially important for tailenders, headenders also need help with headworks and maintenance of the systems (Tang, 1992). These are the premises for irrigation as common resource management.

Much can be learned from local systems of water management that have existed throughout centuries. These studies can also report on local agricultural practice enhancing food security through limited water access (Mul et al., 2011; Lein and Tagseth, 2009; Sokile and van Koppen, 2004; Adams et al., 1994).

This study presents the case study of Engaruka, a Maasai smallholder irrigation farming community located in northern Tanzania. The aim of the study is to examine the local agricultural and water management practices in light of increasing pressure on resources and fluctuations in seasonal water supply. Drawing on common-pool resources theories and non-equilibrium behavior, this article investigates how locally devised mechanisms are influenced by different cropping systems and cultivation expansion and how they deal with growing tensions over water distribution in trying circumstances of water scarcity.

First the article begins with the qualitative methods employed for data gathering. Second, the conceptual framework used for the analysis of data is presented. The third section depicts the case study context including a short review of previous studies. Results are reported according to water management, agricultural practices and recent cultivation expansions. The discussion mirrors the results by analyzing cooperative water allocation, water asymmetry and non-equilibrium behavior in Engaruka. Concluding remarks are provided.

2. Methods

Ethnographic fieldwork was conducted in four sessions alternated with four shorter field visits between 2011 and 2013. Data collection took place during a total of three months, primarily in Engaruka Juu and in the south eastern settlement of Neng´alah. Data was gathered predominantly in Swahili and on a few occasions in Maa. A female field assistant was employed to work also as an interpreter. As I had learnt Swahili, the field assistant only translated questions, but not informants´ answers (for an analysis on translation techniques and positionality see Caretta, 2014a). Qualitative methods were employed. 39 semi-structured interviews were conducted with 20 men and 19 women, all active farmers, between the age of 25 and 65 on multiple occasions. Additionally, 16 focus groups were carried out with a number of informants ranging from 5 to 10 for a total of 118 persons consulted. Sampling of informants was done according to three criteria: 1) residing and farming in a specific location; 2) actively farming; 3) belonging to a certain age group: 20-40 or 40+. Focus groups were gender mixed and gender segregated at times. In exchange for their participation, farmers were either offered refreshments or compensation equal to the amount they would be paid for two hours contract working, which was the average length for the focus group. Themes covered during focus groups were: 1) gender division of labor (see Caretta and Börjeson, 2014b); 2) agricultural practices and the agricultural calendar; 3) perceived weather changes in the last three decades; 4) water management.

The final topic was investigated through participatory mapping: orienting themselves through a 2002 Google Earth® image, informants were asked to find their plot, Engaruka Juu locations and the irrigation canals. Every three months the field assistant carried out a survey of agricultural practices over the course of two years. The eight selected plots were situated in Engaruka Juu and Neng´alah and were chosen based on information provided by owners. Plots had different characteristics in relation to crops cultivated and cultivation history, ranging from 5 to 35 years, either continuously or with fallow periods. In this way a range of different conditions could be studied. Lastly, member checking was employed to increase the reliability and the robustness of the data. This method consists in counterchecking with informants the preliminary data. Furthermore, with every fieldwork session a pamphlet, written in Swahili including numerous images and summarizing previous findings, was presented to informants to gather their impression on the ongoing study, to verify whether data was correct and to stimulate further discussion (see also Årlin et al., in press; Caretta, forthcoming). While triangulation is widely used in qualitative studies, this does not circumvent the risk that the data gathered is imprecise or wrong, thus member checking can enhance transactional validity and research trustworthiness by having informants correcting the researcher´s understanding (Cho and Trent, 2006).

3. Conceptual framework

An irrigation system can be conceptualized as a common property arrangement because it is exclusionary, farmers can be denied irrigation if they do not comply with management rules and requirements, as well as subtractive, one farmer´s use of water hinders the next farmer´s access to the resource. Since water is a common-pool resource, a set of rules must be put in place to restrain farmers from free-riding and irreparably depleting the quality or quantity of water available (Ostrom and Ostrom, 1977 in Tang, 1992). Drawing on the work of Ostrom (1990), Tang (1992) has outlined the operational rules that need to be put in place for a functioning irrigation system: 1) boundary rules delimit who has the right to benefit from the resource; 2) allocation rules detail how much, when and in which order water can be withdrawn by every single farmer; 3) input rules define the amount and type of work that needs to be put in by farmers to be able to be given water; 4) penalty rules state the amount and type of fines that must be paid whenever any other rule has been broken.

These rules can avert free-riding when all shareholders trust the local institution that monitors the use of the resource and encourages cooperation among members (Tang, 1992; Ostrom, 1990). Common property institutions are considered successful when they are long-lasting and they preserve the resource at stake. What is essential to institutional sustainability has been disputed lengthy (for an outline see Agrawal, 2001). On one hand, it has been highlighted that homogeneity among farmers is vital for the functioning of such cooperative arrangements. Differences in landholdings, religion, ethnical belonging and wealth can generate misunderstandings and effectively work against cooperation (e.g Bardhan, 2000). On the other hand, it has been asserted that heterogeneity in endowments creates interdependence among shareholders who are forced to collaborate (e.g. Komakech et al., 2012).

Nevertheless, creating incentives for cooperation is particularly complex in common property regimes such as irrigation systems that are grounded in an intrinsic asymmetry: water flows in only one direction (Komakech et al., 2012; var der Zaag, 2007; Ostrom and Gardner, 1993). Hence, headenders and tailenders have different interests while negotiating equal water allocation or contributing to landesque capital investments as construction of canals and water diversion works (see e.g. Håkansson and Widgren, 2014). Headenders might want more water , but who will collaborate in the maintenance of the overall system, or how will they be sure that tailenders will not destroy upstream infrastructure? And how will tailenders ensure that water is not cut off from them? These problems were defined by Ostrom and Gardner (1993) as appropriation – i.e. water allocation for productive purposes – and provision – maintenance. Such issues are often resolved through the abovementioned set of rules which determine the conditions for the exchange labor-water. Water users are therefore interdependent (Komakech et al., 2012).

Another element that challenges the functionality and durability of common property regimes of irrigation systems is the variability and unpredictability of water supply due to changing inter/intra-annual rainfall patterns (see also Hillbom, 2012; Ostrom, 1990). Flexibility is a key in this context. Demand must be managed to match supply as supply is exogenous and cannot be increased. Negotiations must be undertaken to cope with often changing conditions These circumstances can be described as non-equilibrium behavior. A dynamic set of cross-scalar (e.g. time and space) non-linear trends in the supply of irrigation water result in the shifting location and extent of cultivation. Accordingly, environmental thresholds, such as overgrazing or soil erosion due to soil left bare, might be recurrently crossed without jeopardizing the sustainability of the overall system. In the specific case of irrigation, unpredictability of water supply can be connected to three levels of river flow rate: 1) critical water supplyensures the satisfaction of basic human needs; 2) median water supply sustains productive needs; 3) bulk water supply allows for storage and distribution with external stakeholders (Lankford and Beale, 2007; Lankford et al., 2009). These circumstances that epitomize the intrinsic asymmetric and seasonal nature of water call for pronounced flexibility in local institutional arrangements (see also Hillbom, 2012; Ostrom, 1990).

4. Study site

Engaruka is located 35° 57' 45″ E, 2°59'20″ S on the foothill of the Ngongoro escarpment. Administratively, Engaruka ward is part of Arusha region and is located north of Mto wa Mbu and lake Manyara and south of lake Natron.

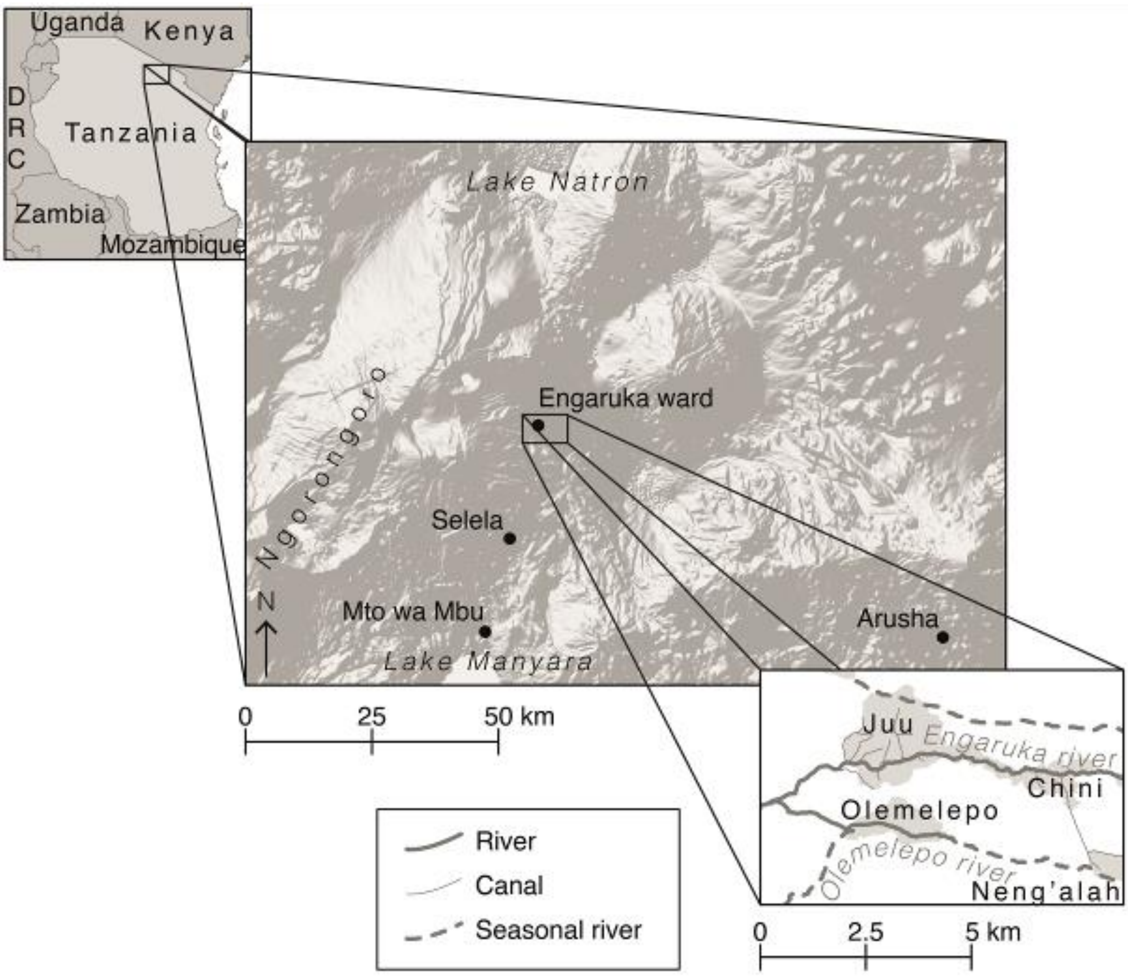

Figure 1. Relative location of Engaruka

In 1977 the current villages of Engaruka Juu and Chini, the latter being circa 2,5 km towards Engaruka basin, were created (see Bertelsen, 1995 for a description of Engaruka). There are also several small settlements in the surroundings of Engaruka Juu and Chini – the biggest being Olemelepo to the south and Neng´alah to the south east - comprising one or several livestock and households enclosures.

Figure 2. An enclosure in the outskirts of Engaruka

The total population of Engaruka ward is 11,121 consisting of 2,171 households with an average size of 5,1 individuals (NBS, 2012). Census data (2002, NBS) shows that the population has increased in 10 years of 3,825 people as it accounted for 7,985 individuals in 2002. The 1988 census accounted for 5372 individuals living in 1004 households (in Bertelsen, 1995). The population has doubled in the last 24 years, this gives an indication of the strain now put on the limited water resources. The inhabitants of Engaruka are all Maasai from the Kisongo and Arusha groups (Sutton, 1986). While the Kisongo is a core pastoralist section of the Maasai, the Arusha are a small agricultural community of the Maasai who originated from Mount Meru and Pangani River valley. The two groups have cooperated with each other socially and economically since at least the late1800s (see McCabe et al., 2010; McCabe, 2003; Spear, 1993).

The market in Engaruka Chini is a busy weekly gathering place for farmers and pastoralists living in the surrounding villages and enclosures. It comprises of two sectors: one for cattle, managed by men, and one for beads, vegetables, clothing, firewood, sugar, tobacco and general petty trading, run prevalently by women. Wholesalers come from the neighboring towns of Babati and Karatu to buy black beans. Marketing of agricultural produce has remained mostly a local venture due to poor road infrastructure (see also Isinika et al., 2005) and the lack of a phone network. This situation negatively affects locals who, for instance, find it more difficult to market their produce or ask for help in case of a medical emergency.

4.1 Previous studies

The abandoned irrigation system at Engaruka has attracted the attention of archeologists who have studied this highly specialized agricultural landscape (for detailed references and a description of the archeological site see Stump, 2006), which is considered the most extensive archeological site of this type in Eastern Africa. According to Stump (2006), stone lines captured sediments contained in the water allowing for the fertilization of the soil. The irrigation system and the field remains have been objects of numerous studies attempting to trace its origins, its development and the reasons for the abandonment of Engaruka (for a complete list of references see Westerberg et al., 2010). It is estimated that the system was in operation between the 15th and the 19th century (Westerberg et al., 2010). According to Sutton (1984), an area close to the deserted site was repopulated in the 1890s and corresponds to the current irrigation system. A study on the recent past and historical development of the current irrigation system during the 20th century is long overdue. This article, however, takes a first step by analyzing the present irrigation management in Engaruka.

5. Water management

Rainfall in Engaruka is scarce and amounts to *ca*. 500mm a year (Westerberg et al., 2010), while potential evaporation is *ca.* 1500mm (cf. CRUTS, 2008). It is therefore classified as an arid eco-climatic zone (Pratt and Gwynne, 1997 in Homewood, 2008). Engaruka has a bi-modal rainfall pattern with rain seasons between October and January and between March and May. While the first rain season is considered to be short with sporadic rains, the second one is long as it rains virtually every afternoon for short yet intense intervals. Farming is viable thanks to the permanent Engaruka River - and two seasonal streams: Olemelepo on the south-west and Makuyuni on the north-west.

The irrigation system depends on all these rivers, but particularly on Engaruka River. The Engaruka River is diverted into two main branches west of Engaruka Juu. One of these branches is directed towards the sub-location of Olemelepo, while the second, which is in effect the main river course, goes through Engaruka Juu itself and continues on towards Engaruka Chini. Canals are cut off from these two river branches, which in turn become furrows when water has to reach single fields.

Canals and furrows are dug into the sandy soil by men using long handled hoes. Canals are commonly less than half a meter deep. Stones are occasionally used to stabilize the banks and avoid their breakage due to water flow. Prior to the application of irrigation water, arable fields are commonly divided into squared basins with two to four meters long sides constituted by raised bunds. Wetting is conducted through basin irrigation with a cascade method taking advantage of the sloping surface (see FAO, 1988 and Fig. 3).

Figure 3. Basin irrigation. The plot is divided in several small basins which are wetted through a cascade method thanks to the sloping surface using a furrow departing from a canal.

Water transmission losses, due to infiltration and evaporation, are common and waterways need to be cleaned and re-excavated twice a year after each rainy season. While the majority of the irrigation system is dug into the soil, a few improvements to limit water dispersion have been made in recent years. Headworks have been carried out – some by TASAF Tanzanian Social Action Fund, which is a state agency – and cement canals have been built in locations where no cultivation is taking place to reach cultivated areas (i.e. between Engaruka Juu and Olemelepo and between Engaruka Juu and Engaruka Chini).

Figure 4. Check-divider constructed by farmers with materials from TASAF in 2013 in Olemelepo.

Additionally, west of Engaruka Juu water for domestic purposes is transmitted through pipes put in place and paid by state agencies in the 1990s. These pipes reach a few homes, primarily those of relatively well-off farmers, but mostly they ensure the continuous flow of water for domestic purposes to Engaruka Chini.

5.1 Kamati ya Maji

The irrigation system is managed by the *Kamati ya Maji* – the water committee which represents the local water users` association. In this article, the rules and dynamics of the water users´ association of

Juu are presented, comparably water management in Engaruka Chini is nearly identical. The *kamati* of Juu- which controls the water distribution in the upper part of the Engaruka River (see fig. 5) is composed of 11 members: a head, a secretary and nine people working as *mgawa maji* – "water divider".

The number of farmers that the board represents fluctuates depending on the season. Customarily, more people farm during rainy season, while less do so during dry season. During repeat focus groups with the members of the committee, they recurrently estimated the number of farmers to be around 300 during rainy season and 200 during dry season. The members of the water users` association are elected by farmers every five years. Anyone can vote and seats in the council are taken up by different people every five years. Both men and women can be elected, but women's presence is minimal. This practice shows the difference between the ideal and the working rules of irrigation management (cf. Adams et al., 1997). Women can potentially sit in decision making forums and become water divider, but in practice the local strong patriarchal structure hinders them from taking such positions. The use of water for productive purposes is a male prerogative. Controlling the irrigation system and limiting women´s active participation is an assertion of masculinity (for further analysis on gender relations in Engaruka see Caretta, 2014c).

Board meetings take place every two weeks or more often if needed. In the case of canal breakage or in need of general maintenance work, the board summons farmers to participate in the repair operations. No monetarily contribution is asked as maintenance work requires only man power. Failure to cooperate leads to fining of 100,000 Tsh (circa 60 USD). This is a considerable sum exceeding the cost of a year of primary school fees. Nevertheless, a member of the water users´ association is adamant:

"A lower fine would encourage people to transgress the norm. This is not a business, there is no money involved in irrigation. You cannot even sell your water. The person who sells it will get a 50,000 Tsh fine." (Author´s notes, February 2012)'

5.2 Water allocation

Irrigation water is divided between Engaruka Juu and Engaruka Chini in 12 hours shifts: from 2am to 2pm for Chini and from 2pm to 2am for Juu. Irrigation is conducted throughout the year in repeating cycles in Engaruka according to three different schedules, depending on the crops planted and on their water requirements:

1. *ratiba ya mazao* – schedule for crops i.e. maize and beans – two to three hours during rainy season every 34 days and one hour during dry season every 24 days. Water distribution then starts again according to the same timing and locations.

2. *ratiba ya mboga mboga* – schedule for vegetables – one hour every 3 days from to 2pm to 3pm;

3. *ratiba ya ndizi* - schedule for bananas – one to two hours every other week;

The most common crops in Engaruka are those of the first schedule (see 6.1). Scheduling is done according to sub-locations and dry or rainy season (Fig. 5 and Table 1).

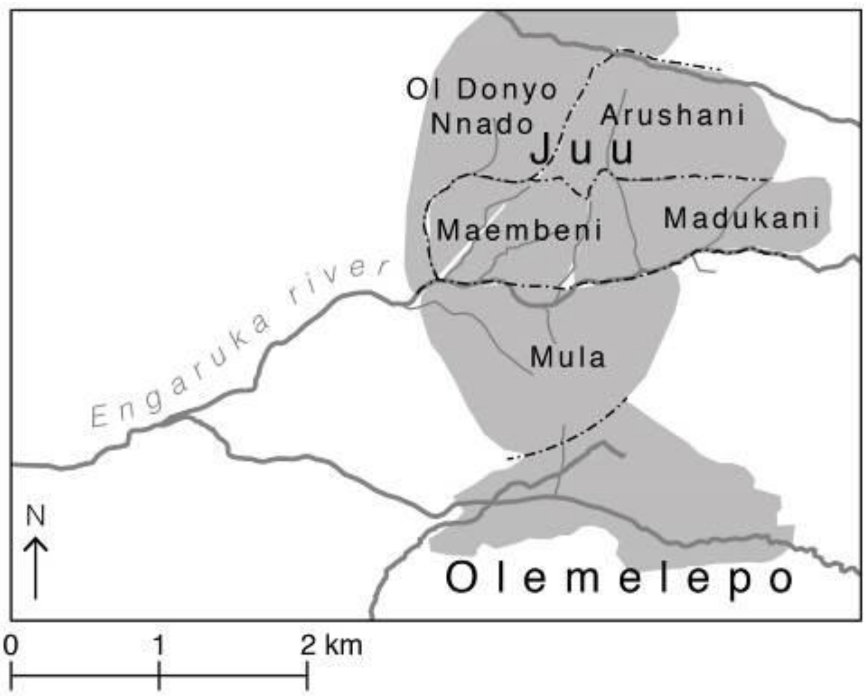

Figure 5. Engaruka Juu sub-locations.

Sub – location	Number of irrigation days per sublocation – Rainy season (March – September)	Number of irrigation days per sublocation – Dry season (October-February)
Arushani	6	5
Ol Donyo Nnado	6	5
Madukani	5	3
Maembeni	5	3
Mula	5	3
Olemelepo	7	5
	34	24

Table 1. Irrigation schedule in Engaruka Juu.[1].

The process of water allocation is based on the seasonal rain pattern and inter-annual weather variability. The general perception among residents in Engaruka is that rain has become more unreliable during the last three decades. During repeat focus groups with more than 100 informants, there was overall agreement that every decade from the ´1980s onwards has been characterized by increased weather variability: droughts (e.g. 1989, 1997, 1996, 2003, 2004) have alternated with bumper harvests (e.g. 1983, 1998, 2001, 2002, 2007). Moreover, informants stated that the timing of the rainy season has changed both in terms of when it starts and ends and season length. To benefit during instable and unpredictable weather conditions and given the increasing population pressure, both seasons are nowadays taken advantage of for crops production, while previously farming was carried out only during the wet season (see also Mul et al., 2011).

Depending on the season and the availability of irrigation water, farmers in Engaruka are given a certain amount of time to water their plot; different crops need different watering regimes. Accordingly, community based resource management varies spatially depending on the local

[1] Data was gathered through repeated focus groups with the *kamati ya maji*. Farmers were consulted separately in recurrent instances both in groups and singularly. Ethnographic research took place between 2011 and 2013. During this time a new committee was elected. New focus groups were conducted with the new members on repeated occasions. The data was confirmed in those instances and validated also through repeated member checking.

hydrography, as farmers cultivate water intensive crops closer to the canals and have to reduce the extent of cultivation plot during the dry season (see also Mul et al., 2011; Lankford et al., 2004).

5.3 Avoiding water conflicts: the mgawa maji

The role of the *mgawa maji* “water divider” is central to the management of water in Engaruka. It should be noted that the *mgawa maji* post can now be taken up by women, which was not the case in the early 1990s (Bertelsen, 1995). S/he is in charge of controlling the irrigation operations and most importantly, keeping track of time ensuringeveryone gets sufficient access to water in the respective sub-locations to avoid conflicts among farmers. The *mgawa maji* does not get paid for his/her work. This position is honorary and endows a certain status and respectability to the person holding it as he/she is entrusted with the most vital local resource.

Because of the larger amount of water available during rainy season – which commonly consists of intense but rather short afternoon showers for a period of up to two and a half months - each sub-location is given more time to irrigate fields. This cycle is ten days shorter during the dry season, when farmers receive only one hour of water roughly every three weeks and are forced by the water users´ association to reduce the size of the field that they plant and to farm as close to the river as they can. The average plot size in Engaruka is less than 1 ha, which is reduced to half ha during dry season. In this case, the *mgawa maji* is responsible to verify that the rule is followed by every farmer. This regulation contributes to the declining number of people farming during the dry season: from 300 roughly to 200, according to the *kamati ja maji.* When not farming, farmers spend more time herding livestock in search for water and pasture.

It should however be noted that there are not only 300 plots farmed in Engaruka Juu. Farmers have an average of about three plots in different locations. This situation has two main implications. First, farmers carry out irrigation on different days depending on the location of the plot and the respective irrigation schedule depending on the type of crops that they have planted. For instance, a farmer might have a vegetables plot in Ol Donyo Nnado, a maize and beans plot in Arushani and a bananas plot in

Maembeni. In this case he/she has to take into account three water schedules with different timing, frequency and length of water allocation.

Second, farmers are not singularly headenders or tailenders in Engaruka as farmers tend to have one or two plots upstream which are cultivated year-round and one downstream, which is cultivated primarily with maize during rainy season. They justify this practice by referring to the better quality of the soil in the downstream plots which confirms Stump´s (2006) idea of Engaruka as being a sediment capture type of irrigation system. Maasai farming decisions are grounded on knowledge about soil as for instance stickiness and softness. They refer to these tactile characteristics as being used to determine soil fertility (see section 7.2).

Figure 6. View of plots of Engaruka Juu during rainy season.

The general rule is that everyone who owns a plot and participates personally or through a family member with maintenance and repair work, regardless if it is a man, a widow or a single mother, is entitled to irrigation water every 24 or 34 days. As water competition is higher during the dry season the water divider must be on site. As there are at least two *mgawa majii* for each sublocation, they take turns in checking water allocation. Their presence is fundamental to avoid conflicts between farmers due to breaking of rules. For instance water stealing leads to a 50,000 Tsh (26 USD) fine and delayed release of water to the next farmer is fined with 10,000 Tsh (5 USD). Arising conflicts between neighbors are most often solved on the spot through the mediation of the *mgawa maji*. If the matter cannot be settled directly or during rainy season the *mgawa maji* is not on site, the issue is taken to the board, which summons a meeting no later than the following day.

In multiple interviews members of the *kamati* and farmers, few cases of conflicts and fines were reported. The members referred to a quarrel that turned deadly in 2002 as a game changer. Two farmers had opened the sluices to irrigate at the same time during dry season. This circumstance triggered a fight where one manwas killed by the other. As a result of this incident the *kamati ya maji* drafted and approved stricter rules for water sharing and implemented a more decentralized organizational structure with more *wagawa maji*. Before 2002 there were only three *wagawa maji* for the whole Engaruka (Juu, Chini and Ndimi). With this deadly incident highlighting the pressure on water and land due to population increase, regulation of water management was strengthened by having more water dividers and by increasing fines, which reportedly improved the compliance with rules. It was also established that whenever a farmer wants to establish a new plot or take it up again after a fallow period, he has to inform the *kamati ya majii* and consult the leaders of his/her sub-location. When both authorities give their consent, he/she can proceed to dig the canal leading to the plot.

6. Agricultural practices

All interviewees assert that agriculture is the most important livelihood for them and they do not hesitate to state that agriculture has become more important than herding. Informants claim that cultivation in Engaruka started before villagization in the ´1970s, probably in the ´1950s thanks to the Arusha (for an overview of Ujamaa´s consequences on the agricultural sector see Isinika et al., 2005).

This notion is confirmed by Bertelsen (1995). Among interviewees participating in my study there is also a general agreement that after *Ujamaa*, cultivation expanded, notably in Engaruka, becoming the most important activity. Bertelsen (1995:11) asserts that in "1974 and again in 1990s new land was distributed". She however does not provide figures or maps to support this information.

6.1 Traditional crop mix

Maize and beans, consistently intercropped in lines, are without a doubt the most wide spread cultivation mix in Engaruka ward. These crops can be productive even with limited irrigation, as in Engaruka. All informants participating in this study cultivate maize and beans.

Maize is sowed in January right after the short rains (October-January) and is harvested after four months. After March, the long rainy season begins and a new batch of maize is sowed in April and subsequently harvested between September and October. While maize is cultivated twice a year, black beans are grown between April and October during the long dry season. Between October and January, during the short rains, the land is left to fallow for three months. Black beans are partly for subsistence, but are also purchased by wholesalers coming from the town of Babati roughly 150km to the south. A sack of 120kg is reportedly sold for 80,000Tsh (48USD) which is enough to pay primary school fees.

When questioned about this ubiquitous mix, farmers generally assert that "the land of Engaruka is good only for maize and beans. You get better yields than potatoes and cassava" (Author´s note, August 2013). Focus group and interview data shows that some plots have been farmed continuously with this mix for the last 20 – 30 years. Soils in Engaruka are volcanic, rich in mineral nutrients. Their agricultural potential is enhanced by mulching (pers. comm., L-O Westerberg, Dept. of Physical Geography, Stockholm University) and by mixing of nitrogen fixing beans and maize (cf. Sharma and Banik, 2014).

Practices carried out by farmers are listed according to their order of application:

1. Fencing, done by gathering and piling thorns and branches around the plot, keeps cattle and goats off the crop;

2. Contouring, promoted by the national farmers´ network MVIWATA (Mtandao wa Vikundi ya Wakulima Tanzania) (for an analysis on MVIWATA see Isinika et al., 2005) in the last decade and done twice a year after the rainy seasons, prevents water erosion as it maintains the soil on site and preserves soil moisture. Farmers say it takes longer for the soil to dry out if contours and bunds are in place;

3. Tilling, on the other hand, farmers state, facilitates water absorption and they describe the soil becoming softer after it has been opened up and turned upside down by the ox-drawn plough;

4. Planting of maize and beans is done through intercropping. Informants say that intercropping is a preferred choice of cultivation also because even if one crop fails, the other may remain to be harvested. Additionally, more greenery is produced to feed animals;

5. Weeding is carried out by women (for an analysis on gender division of labor see Caretta, 2014c);

6. Crop residues left on the spot, after irrigation, become mulch which effectively protects the soil from wind erosion and replenishes soil fertility, according to farmers. This observation is confirmed also by experimental studies done on maize in Tanzania (i.e. Enfors et al., 2011; Makurira et al., 2011 and 2007).

6.2 *Horticulture*

Banana was first planted in Engaruka in the ´1980s and so is a relatively new crop, according to informants. The few farmers who cultivate it use bananas for resale. Banana gardens have the darkest and most fertile soils in Engaruka as mulching is constant in bananas gardens, as stacks of bananas branches are left on the spot.

Based on the information of the *kamati ya maji* there are 21 farmers who have started to adopt new cultivation routines. They are all men, who either specialized in agriculture in secondary school or who have attended a workshop given by the agricultural as MVIWATA. Horticulture took off in 2009 and this change has also brought about a new irrigation schedule. During repeated field visits in the course of three years 2011-2013 more farmers, especially young men, started cultivating vegetables for sale. All the plots of those farming vegetables are on the western side of Engaruka Juu in the sublocations of Madukani, Maembeni and Ol Donyo Nnado (Fig. 7). They are closer to the Engaruka River from where they can withdraw water directly with buckets, whenever the one hour irrigation water they are given every third day is not enough. Reportedly, such practice needs however seldom to be carried out.

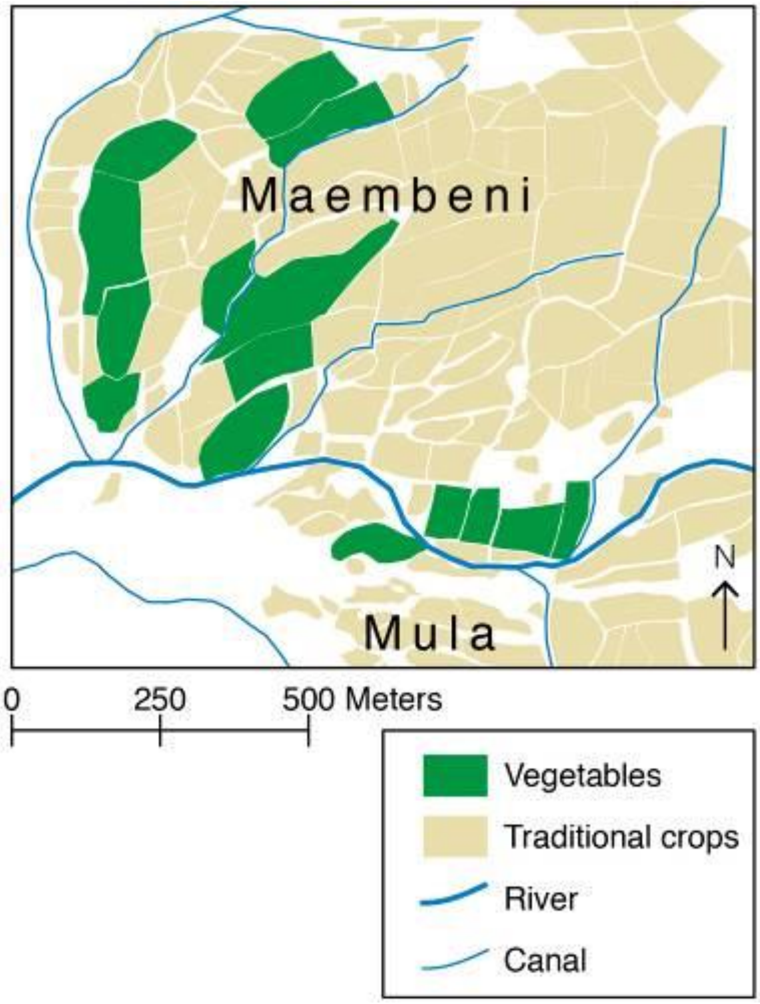

Figure 7. Location of vegetable plots in Engaruka Juu.

The most common vegetables cultivated in Engaruka are: Chinese cabbage, onions, tomatoes, soya beans, peppers. These are high value crops that are planted up to three times a year. Recently

MVIWATA, the Tanzanian network of farmers´ groups, has carried out workshops where early adopters were given advice on how to cultivate tomatoes. Tomatoes however, according to some informants, were already brought to Engaruka in the ´1980s and have since then mostly been cultivated for sale. All horticultural crops are labor intensive. Onions, Chinese cabbage and peppers need to be weeded twice in the three months period they are growing, farmers are advised to spray crops with pesticides if it rains frequently because they can quickly develop pests.

Some drought resistant crops such as sweet potatoes, cassava, groundnuts and cowpeas are also cultivated, although to a much lesser extent. The last is also intercropped with maize by some farmers. Horticultural crops are planted in interchangeably different plots every year. For example, a plot can be cultivated two seasons with maize and beans, and the following year it is planted with vegetables.

Wholesalers from Karatu and Arusha drive their trucks directly to Engaruka to collect the horticultural produce. To buy seeds and pesticides in order to ensure a successful harvest, farmers reportedly need to have a starting capital or get a loan from an NGO or a bank. All early adopters of horticulture reported in repeated occasions and confirmed that they could pay back the loans and they were making sufficient gains from their produce to pay school fees for their children, sustain their family and buy seedlings and seeds for the following season. According to farmers, for instance, one kg of Chinese cabbage is worth 800Tsh (0,5 USD) and a ten liter bucket full of tomatoes is sold for 1000Tsh (0,6 USD). Farmers state that thanks to vegetables they do not need to sell a cow to pay school fees anymore. Selling of livestock is thus only needed when monetary funds are lacking to pay school or medical expenses, or most importantly, when harvests fail due to drought or floods.

Of the 21 farmers cultivating vegetables, four purchased a plot and six rent. The other 12 are the original owners of a plot. While customary land tenure prevails, the head of village, the owner of the local camp site and two locals who are state employees purchased the plots. They all have someone else cultivating the plot on their behalf. Reportedly a 1.5 ac plot is rented for 500,000 – 600, 000 Tsh (c. 250 – 320 USD) for three months, the time needed to harvest vegetables. 1 ac rent is 400,000 Tsh (c .210 USD). Payment does not need to be up-front, it can be delayed. Interviewees emphasize that such a sum is not difficult to gain from selling high value vegetables to wholesalers and local farmers, who resell the product at local markets. Shared rental arrangements have also started to emerge. For instance, the owner of the plot pays for seeds and pesticides, while the tenant cultivates the plot. After the sale of the produce, the profit is shared among them.

7. Agricultural expansion

As discussed in the previous section, new types of cultivation are emerging and Engaruka ward has witnessed the continued expansion of agricultural cultivation since mid ´1970s to the early 1990s, according to Bertelsen´s report (1995). Hence, changes are not something recent, but rather a constant of this irrigation system. For instance, the sub-location of Olemelepo has been expanding in the last ten/fifteen years towards the west, closer to the permanent canal and the temporary Olemelepo river. Here part of the southern fields of the abandoned irrigation system, whose stone lines can still be seen, have also been taken up again and cultivated (Fig. 8).

Figure 8. New cultivation in Olemelepo. The two Google Earth® images from September 2002 and December 2010 depict the expansion of cultivation in the western area of Olemelepo closer to the

branch of Engaruka River and to Olemelepo River (35° 96' 24″ E, 3°01'28″ S). The two satellite images were taken during dry seasons and are hence comparable.

However, the most interesting and evident developments of the irrigation system are taking place further down in system. The uptake of new plots is a recurring topic when interviewing farmers in Engaruka Juu. Many affirm that they have plots in what they call Ndimi: a vast rangeland area extending from Selela – on the road towards Mto wa Mbu – and Engaruka.

Two recent expansion areas have been the object of deeper investigation: Neng´alah 3°01' 02″ S, 36°00' 50″ E on the - SW of Engaruka Chini - and Baraka 3°03' 14″ S, 36°01' 05″ E. These two locations, because of the different temporality and the characteristics of their development, exemplify two different strategies of agricultural expansion adopted by the Maasai in Engaruka.

7.1 Neng´alah

In 1983 there was a bumper harvest and cultivation in Neng´alah in the area of Engaruka, according to focus groups informants. However, before 1991 no irrigation was done in Neng´alah and cultivation of maize was carried out only between April and September, following the long rainy season (March-May). The canal connecting Neng´alah to Engaruka River, drawing water from Engaruka Chini, was built in 1991 by farmers living in nearby enclosures. From that year onwards, cultivation in Neng´alah has been periodically expanding toward the south and the north (Fig.9).

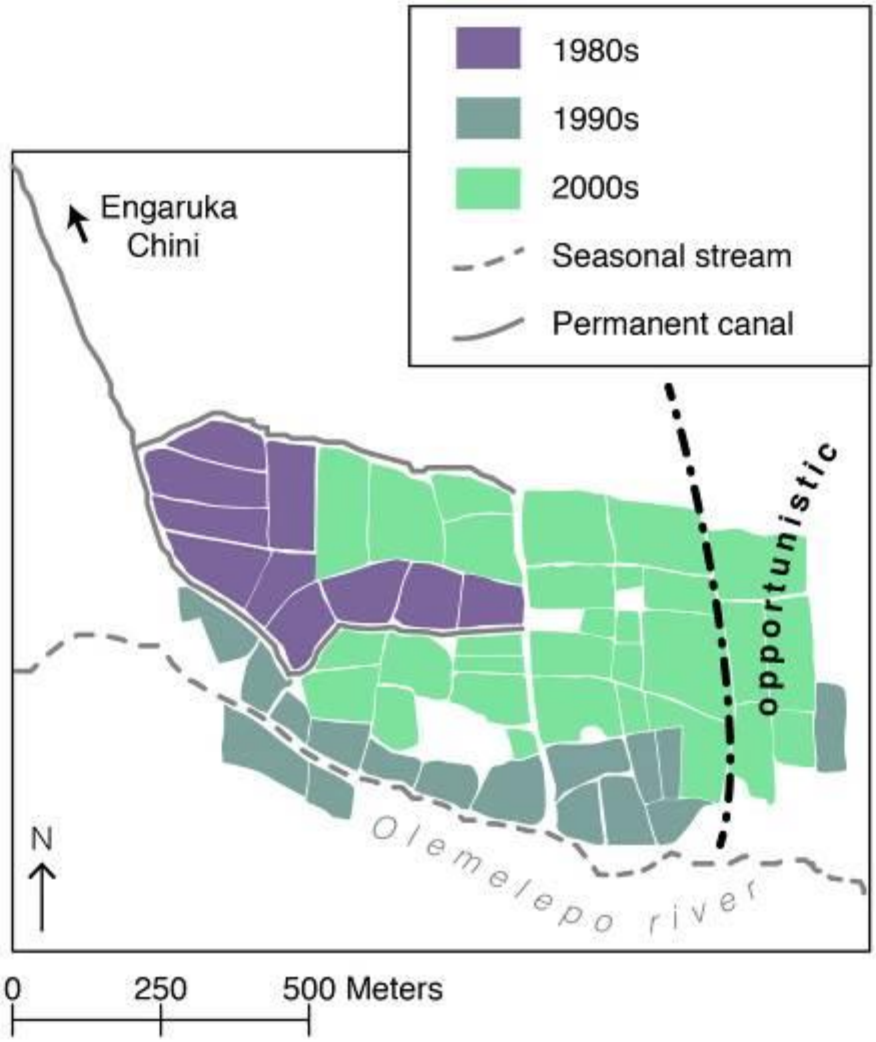

Figure 9. Neng´alah cultivation development.

The most eastern area of Neng´alah started to be cultivated in 1998 when the abundant La Niña rains made it possible to clear and cultivate more plots. Succeeding that year, this sector of Neng´alah has been farmed only when rains have been sufficient and irrigation water could reach the western most tip of this area. Hence, it is not a permanent type of expansion, but rather a resourceful one, completely dependent on the weather. Reportedly, the last rainy season that made the cultivation in the eastern most fields possible was in 2008.

Farmers in Neng´alah, as in Engaruka Juu, cultivate maize twice a year and intercrop in with black beans, which are harvested once a year. With regards to the irrigation schedule, Neng´alah is a sub-location of Engaruka Chini. Irrigation is allocated monthly here: four days of water during dry season and five days during rainy season. The area can count on the water discharge of Olemelepo River during rainy season. Six farmers cultivate bananas in the whole location. As in Engaruka Juu, bananas' cultivators can benefit from a special irrigation schedule which gives them two hours of irrigation water every other week.

At the moment there are roughly 40 plots in Neng´alah out of which less than half are cultivated year-round. These plots are located closer to the canal, are planted with bananas which are not a seasonal crop nor are owned by farmers residing in Neng´alah. In fact most of farmers cultivating here live in Engaruka Juu or Chini and take advantage of the rains to farm an additional plot. Water for irrigation can, in fact, be insufficient at times, that is why farmers during dry season have to limit their cultivation to one acre. Water for household consumption is roughly six km away, which women go to collect once a day. Given the difficult environmental and living conditions, Maasai residing in Neng´alah explain, as opposed to those living in Engaruka Juu, that pastoralism is still the most important livelihood for them as it ensures their subsistence even when the weather is unreliable and cultivation is not viable. In fact, in case of drought, branches and trees are cut to let cattle and goats eat them to keep them alive. They are then subsequently sold to buy grains and pay for general expenses. Livestock consequently remain central to the survival of the people of Engaruka.

7.2 Baraka

The same situation is depicted by interviewees residing in Baraka, which consists of a handful of enclosures to the south of Engaruka Chini, roughly ten km away, one and a half hours walking from Engaruka River, which is the only and the nearest permanent source of drinking water. The first farmers started clearing plots in this area, following the same bumper harvest of 1983. However, what made cultivation expand substantially here were the 1998 La Niña rains. Since that year, those living in the enclosures surrounding the agricultural area of Baraka have formed a *Kamati ya Ardhi* literally "the soil board/committee", which is in charge of keeping track of new plots being cleared in order to avoid reducing grazing lands to a minimum. The area surrounding the cultivated area of Baraka is characterized by trees and shrubs where goats and cattle from the whole of Engaruka ward graze.

According to interviewees, when the *Kamati ya Ardhi* was established in 1998, 23 farmers had started farming in Baraka. The area of cultivation expanded during the 2000s (Fig. 7). In August 2013, when interviews were carried out, 88 farmers were known to the *Kamati ya Ardhi*, each having a one acre plot and farming in Baraka.

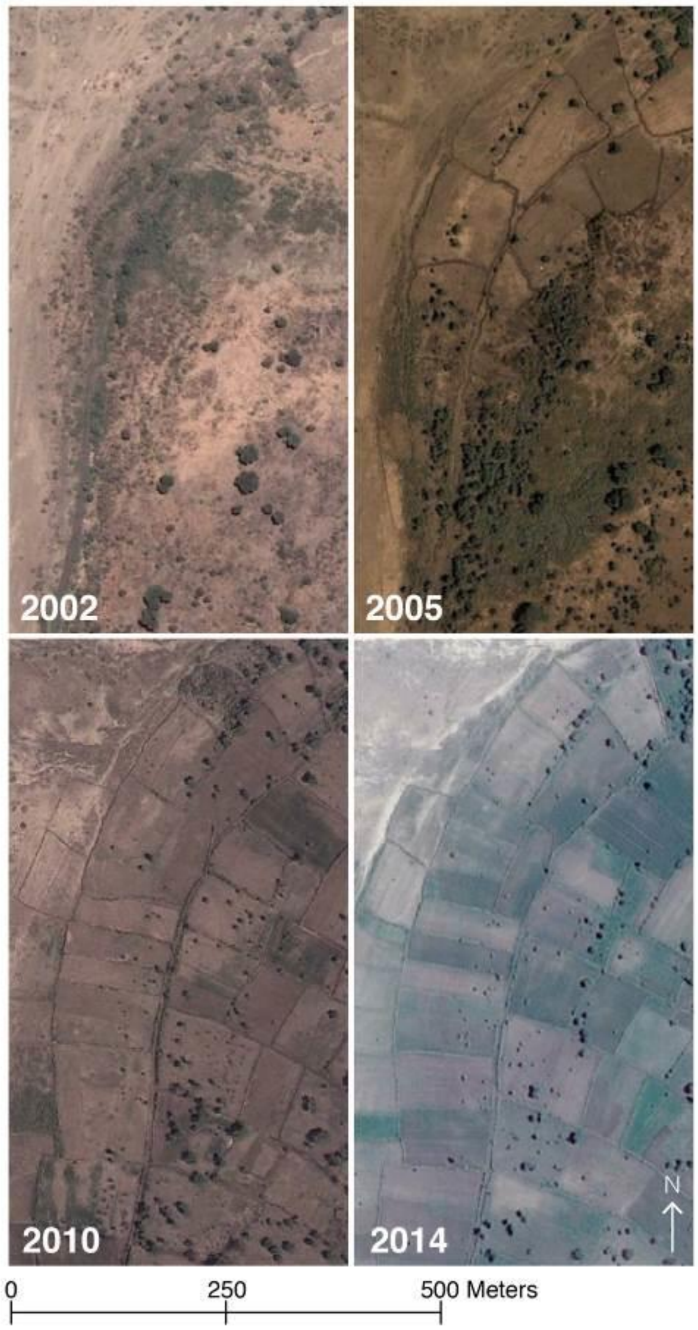

Figure 10. Baraka cultivation development. The four Google Earth® images from September 2002, October 2005, December 2010 and January 2014 visually convey the successive clearing of bushes

and trees, the allotment of plots and the further addition of more plots in the location of Baraka 3.0533442,36.0193236,1908 (36° 01' 93″ E, 3°05'33″ S).

During the last decade, these 88 farmers have been making use of three canals called Oltulelei, Oleletaiku and Olelaigwanani, each several kilometers long, which they excavated autonomously to collect the water runoff from the Ngongoro escarpment during the long rainy season. Therefore, they farm only maize and they can cultivate only between April and September.. They report that the land is very fertile and that it is enough to irrigate maize twice during the course of four months to have a successful harvest. They state: “Soil here can be irrigated less often because it maintains moisture for a longer time than in Juu” (Author´s note, August 2013). When questioned about how soil fertility can be assessed they assert: “Soil fertility does not diminish here with every harvest. It is fertile here because there were bushes and trees earlier here” (Author´s note, July 2011).

The fact that the soil is more fertile in the whole Ndimi- the area comprised between Engaruka Chini and Selela - is common knowledge among all the informants. Several residents of Engaruka Juu report to be farming in locations in Ndimi which are more than ten km away because the land is plentiful and they know they can get a good maize harvest. One summarizes: “Soil in Ndimi is better than in Engaruka because the water coming from the mountains is black” (Author´s note, August 2013) referring to the nutrients being flushed down the Ngorongoro escarpment, which goes along Stump´s (2006) inference that the abandoned system took also advantage of sediment capture for cultivation. Moreover, when asked to describe the difference between the soils in Ndimi and in Engaruka Juu, one farmer illustrates: “the soil in Ndimi is black and soft, while in Juu it is sandy and water evaporates more quickly. In Juu the soil is sand, when it is wet you sink, in Baraka when you irrigate the soil gets stuck under your feet” (Author´s note, August 2013). This statement probably reflects the higher clay content in Ndimi (Baraka), than in Engaruka Juu (pers. comm., L-O Westerberg, Dept. of Physical Geography, Stockholm University).

8. Discussion

The discussion mirrors the previous results sections. It is divided into three themes related to cooperative water allocation, water asymmetry and non-equilibrium behavior. The discussion concludes with some questions that remain open regarding the future of this irrigation system.

8.1 *Cooperative Water Allocation*

The *kamati ya majii* is the institution in Engaruka that regulates the appropriation of water as a common property resource, through the allocation of irrigation water through three different schedules, and its provision through the maintenance of the irrigation infrastructure (see Ostrom and Gardner, 1993). Appropriation and provision are regulated through four sets of rules (see Tang, 1992): 1) boundary: members are the 300 or 200 individuals farming during the rainy or dry season; 2) allocation: water is distributed according to three seasonal and crops-based irrigation schedules; 3) input: maintenance and construction work that must be put in twice a year to be allocated water; 4) penalty: fines must be paid whenever water is stolen, sold or when it is delayed to the next shareholder.

While, “no single set of rules is good for all irrigation systems” (Tang, 1992:123), some strengths have been singled out of a successful cooperative common property regime. The organization needs to be trustworthy, credible, representative and people should be able to identify with it. The operations need to strive towards equity which ought to be achieved through democratic decision making processes grounded on principles of solidarity and cohesion in order to avoid conflict. Equity can only stem from local transparent negotiations which users carry out continuously (Boelens and Davila, 1998).

None of the hundred plus farmers that I have interviewed has ever voiced any complaint towards the water users´ committee. Members are elected with an open process of candidacy and do not seat for more than one term. Such prerequisite makes the committee less prone to corruption or favoritism. The guiding principle of the committee according to the current chair is to avoid conflict. Subsidiarity through the *mgawa maji* allows for localized solutions for localized solutions to water distribution (cf. Lankford and Beale, 2007). While, they can potentially turn into free-riders by taking advantage of their position, this does not happen when monitoring, as in the case of Engaruka, it is reciprocal and the irrigation organization strives towards accountability. While the water divider is there to ensure that farmers do not irrigate for a longer than the time slot they are allocated, farmers expect the *mgawa maji* to be on site and to check whether they get the water at the right time. If he is not there and issues arise they will report him to the water committee which will summon the *mgawa maji* and decide to either fine or relieve him/her from his/her duties (cf. Tang, 1992). This same dynamic has been described by Ostrom (1990) in her analysis of the role of the so-called "ditch-rider", the local equivalent to the *mgawa maji*, in the *huerta* irrigation system nearby Valencia.

8.2 Water asymmetry

According to Komakech (et al., 2012), social and spatial proximity are prerequisites for a functioning common-pool regime in a condition of water asymmetry. Moreover, social homogeneity, almost equal landholdings size, and involvement in water allocation decision making are attributes of a functioning and long-lasting institutions (Agrawal, 2001; Bardham, 2000).

These are characteristics that can be ascribed to the organization of water allocation in Engaruka. The farmers all cultivate in a relatively limited area and are all Maasai. Farms that reach one ha are few in number and in any case, during dry season, everyone is obliged to reduce the cultivation area to half ha per plot. This technique can be considered an improved water management strategy as it maximizes water productivity – defined as the ratio of agricultural product and water consumed (van Halsema and Vincent, 2012) - by reallocating water to other farmers. In fact, carrying out deficit irrigation– i.e. irrigating less than the full amount of water available – has the potential to increase water productivity (Molden et al., 2010). Such is the case in Engaruka: farmers follow a very strict schedule whereby irrigation water is applied in a limited but sufficient amount to allow for the growth of crops.

Decisions are taken by the *kamati ya maji*, which is elected through popular vote. While formally eligible to sit on the committee, women seldom do so due to a strong patriarchal gender norm which effectively limits their participation by relegating them practically and discursively to a subordinated position (for an in-depth analysis see Caretta, 2014c). This dynamics sheds light on the existing difference between ideal and working rules (cf. Adams et al., 1997).

Distribution of landholdings in Engaruka is clearly influenced by soil quality, water availability and access. First, there is more pressure on land close to the intake and along the main canal. As in the Usangu plains, Tanzania (Lankford and Beale, 2007), plots that can be irrigated all year round are cultivated with water intensive crops as vegetables. Second, in semi-arid environments the water holding capacity of soil shapes cultivation patterns. On one hand, farmers put in place water conserving practices as tillage and mulching (see also Enfors et al., 2011; Makurira et al., 2011 and 2007). On the other hand, as in Bangalala in Pangani, Tanzania (Komakech et al., 2012), farmers in Engaruka are aware that plots downstream have a higher water retention capacity owing to its higher clay content, and specifically in Baraka, they assert that a good maize harvest can be obtained only with one irrigation turn. Owing to the fact that farmers in Engaruka have mulitpleplots in different locations in the area where they cultivate different crops and so benefit from different irrigation and soil fertility and water retention. Therefore, headenders and tailenders are, in essence one and the same in Engaruka. This twist of circumstance counteracts water asymmetry by effectively inhibiting unilateral action, as described by Komakech in Bangalala, Tanzania (et al., 2012).

8.3 *Non-equilibrium behavior*

This study shows the adaptability of Maasai who decide what, where and how much to farm depending on local circumstances i.e. weather, soil, water availability and marketability of the produce. This adaptability can be defined as non-equilibrium behavior for three reasons.

First, the area of irrigation is variable in Engaruka. Command area and boundaries change depending on rainfall variability which determines supply. The area of cultivation is expanded in wet years, as for instance during La Niña, and retracted in dry years. An inter-annual difference of several hundred acres of cultivated land occurs because farmers are bound to comply with the rule that limits plots to one acre during dry season. As in the Usangu plains, along the Great Ruaha River (Lankford et al., 2009) this swing can be attributed to three environmental factors: 1) a high variability in the Engaruka River flow rate, 2) a sizeable amount of *irrigable* land on the plains, 3) several canals that can distribute water when the supply its abundant. Irrigation expands and retracts intra- and inter-seasonally. Hence, like grazing, it creates a succession of different patches through the landscape, which is considered a sustainable measure for agricultural management (see also Lankford and Beale, 2007).

Second, the nature of water does not constitute the basis for a predictable regulatory water management. Given that water supply is exogenous and there is no local storage capacity, management challenges are highly variable from one year to the other. Irrigation planning is flexible, contextual, seasonal and circumstantial and is best tackled through localized water allocation. water rights are, therefore, time-limited, adjustable and informal (see also Lankford, 2004). Water supply levels shift between critical needs ensuring the satisfaction of basic human needs and median needs-sustaining productive needs (Lankford and Beale, 2007; Lankford et al., 2009). Consequently water demand must be managed to match supply intra- and inter-seasonally (Lankford et al., 2009).

Finally, it is important to keep in mind that non-equilibrium behavior is possible because farmers have other sources of livelihood and can reduce their withdrawal rate to share water with other users and whenever supply is limited (cf. Lankford and Beale, 2007). Livestock remains crucial to the livelihood of Maasai, particularly when harvests fail or emergencies arise. These reasons coupled with population pressure and the increasing importance of monetary economy, are among the main drivers prompting flexibleexpansion of cultivation when water supply allows it and horticulture close to the canals.

8.4 Hydrosolidarity and customary land tenure, but for how long?

The term hydrosolidarity can describe the circumstances above mentioned. It defines ethically integrated land, water and ecosystem management (Gerlak et al., 2011). This concept can help to explain the cooperation between downstream and upstream users, which is possible if the water flow is understood and monitored continuously (van der Zaag, 2007). While this is the case in Engaruka nowadays, it remains to be seen how long these conditions will hold.

Population pressure is increasing and so is demand for food while at the same time water availability is fluctuating and becoming more limited. Farmers in Engaruka respond to these circumstances in different ways. On one hand, they use the water available as efficiently as they can by 1) sharing its use among all active farmers in a given season, 2) reducing the size of plots and allowing more residents to cultivate, 3) monitoring the allocation of water to avoid free-riding, and 4) irrigating year round and expanding cultivation whenever abundant water supply allows for it.

On the other hand, some farmers have started cultivating water and labor intensive, and remunerative horticultural produce which they sell at local markets and to wholesalers. This type of cultivation has already triggered some changes: a new irrigation schedule, rental arrangements and the sale of some plots. Since 2001 Tanzania land ownership is governed by two co-existing tenure systems, customary and statutory. (Isinika et al., 2005), Engaruka farmers, regulated by customary rules, do not have land registration certificates, however, in 2014 state deputies held a seminar in the area to inform farmers about the upcoming switch to the statutory system Bertelsen (1995) reports that when someone wants to sell a land parcel the transaction is registered by the head of the village. Farmers in Engaruka assert they have a secure land tenure situation, despite lacking documentation.. According to customary rules, men inherit land from their fathers and if the father wants to sell a plot, he must have permission from his adult sons.. Farmers claim they have full control of the land and that no one can take it from them whenever they leave it fallow.

The ongoing emergence of horticulture in Engaruka has brought about some, changes, albeit limited, in land ownership and rent. Currently, there are circa 20 early adopters of vegetables but what will happen if their numbers will increase? So far farmers were required to ask for permission from their neighbors to start cultivating a new plot and the *kamati ya maji.* Given the income generated by vegetables, the increasing number of young farmers with a formal agricultural education and the need to pay school fees, an increase in the number of horticultural producers can reasonably be expected. These practices will put extra pressure on the already limited and highly variable water supply of Engaruka River. Conflicts among farmers will likely increase and the local common resource institution will be faced with many more challenges. When questioned, however the *kamati ya majii* members do not foresee plots being concentrated into the hand of few rich individuals and, they say, if that would be the case in the future, they would proactively react against it.

The potential increase of horticultural production and the transition to a new land ownership system pose some uncertainties. What if more plots are bought and will ultimately concentrate in the hands of few people? Will the *kamati ya maji* be able to counteract these dynamics as they assert?

The current secure perception about customary ownership rights might spill into the upcoming statutory ownership system, as highlighted by Isinika et al. (2005), and ensure titling to the same long term owners. It is nevertheless true that the formalization of land rights can facilitate the accumulation of land in the hands of few smallholder farmers who have a bigger starting capital (see Cousins, 2013). Since these changes are evolving as this paper is being written, it will be relevant to focus on these questions in future studies.

9. Conclusion

To counteract food insecurity in Sub Saharan Africa, enhancing agricultural productivity in semi-arid areas by better managing the availability of water is crucial. Accordingly, farmers in Engaruka have been capable of balancing an increased production of crops (vegetables) with the essential of maintaining natural resource integrity (water).

Ostrom (1990:14) argues "that "getting the institution right" is a difficult, time consuming and conflict-invoking process". The data presented in this article illuminates the dynamics of this process by showing Maasai agro-pastoralists´ adaptability to changing and erratic weather conditions either by strictly regulating water allocation time and extent depending on crops´ water requirement and seasonal water supply, extending cultivation opportunistically or by selling livestock in times of emergencies. Horticulture emerges also as a relatively quick means to recover from droughts and to sustain the monetary needs of families.

Locals´ livelihood is ensured by community based resource management through the water management committee which mediates conflicts in water distribution and mobilizes labor for the functioning of the system. The institutional arrangement of water management in Engaruka is an open horizontal, yet male dominated, forum consisting of elected representatives and the crucial mediator figure of the "water divider", which ensures the smooth and timely allocation of water.

Water management in a non-equilibrium state is defined by Lankford and Beale´s (2007:169) as: "A dynamic irrigation system can be characterized by its ability to dramatically change the area supplied, planting schedule, number of farmers supplied, run-off volumes and efficiency". This statement describes the situation in Engaruka where water abstraction and allocation depend upon a variable inter- and intra-annual water supply.

Small common property regimes can be conflictual and should not be idealized (Lankford and Beale, 2007). While conflicts exist in Engaruka, they are reported to be quite rare. This circumstance is due to a decentralized management system materialized in the figure of the *mgawa maji*, who is accountable both to farmers and to the central water committee, and a stringent set of rules on water allocation based on seasonal water availability.

Engaruka is a homogeneous and interdependent community where headenders and tailenders are often the same people and are hence inhibited to carry out unilateral action that will negatively affect other farmers (see also Komakech et al., 2012). Additionally, the *kamati ya majii´s* preoccupation to avoid conflict responds to the criteria of hydrosolidarity. Such behavior is guided by the framing of water as a common good which needs to be dealt with mutual understanding and ethical considerations in order to resolve and avoid conflicts through shareholders participation and uniform information about water rights (cf. Gerlak et al., 2011). Against the backdrop of population pressure, limited and fluctuating water availability and the potential increase market demands on locally grown agricultural products, it remains to be seen how and for how long hydrosolidarity can be maintained in Engaruka. This study has shown that dynamic flexible irrigation management allows expansion and retraction of cultivation. This dynamics is crucial for the satisfaction of basic and productive needs in Engaruka and for the avoidance of water conflicts through demand management and as such can effectively represent an answer to ever-changing and increasingly limited water availability.

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