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Role of Bryophytes and Tree Canopy in Mist Trapping in Mt. Marsabit Forest

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Abstract
Mt. Marsabit forest, is an isolated Tropical Rain Forest, oasis, located 560 Km north of Nairobi, Kenya; and surrounded by deserts of Chalbi, Kaisut and Bubisa. The forest is under threat mainly by anthropogenic effects before the forest biota is studied. This research was to investigate the role of bryophytes and forest canopy in trapping mist water, for supporting Mt. Marsabit forest community development. The experiments were located 1450 m. asl windward of Mt. Marsabit. Stem simulates of varying circumferences were dressed with bryophytes and bryophytes mounted mist traps were located on same site. The water retention capacity was 6 times own dry weight with a hygroscopic capacity of 13%. The mist water trapped by bryophytes was 8 liters of water / m ^{2}/ mist day translating to 196 mm of rainfall per year. The stem simulates of 20 cm circumference, 50 cm long trapped 30 ml of water per mist day using surface area of 0.05 m^2 translating to 914 ml of water per m^2 per mist day equivalent to 65 mm of rainfall per year. The study revealed that vegetation is an important catchments area surface (attract rain) whose loss leads to reduced water resource for plant and animal use; climate moderation. Further, mist water is the compensation factor that supports the forest ecosystem. The cooling effect of water is lost with the loss of vegetation. The loss of water leads to drier environment with climate change as the ripple effect. The change in river regimes and the general hydrologic cycle is due to loss in vegetation, where mist water was not accounted for by science. The mist water resource is renewable water resource that can be used to recharge ground water, conserve and rehabilitate forest and provide water for domestic, agricultural and industrial use.

INTRODUCTION

Tropical forests have received considerable attention for reasons of their rich biota diversity (Gradstein et al, 2000,), and they contain large stocks of Carbon that potentially influence the global carbon cycle, climate change (Fearnside, 2004) and water catchments (Queensborough *et al*., 2007).
Forests and vegetation in general are accepted as water catchment, climate moderators and CO_2 sink. The forests act as a sponge for water and slowly filter water to the soil, rivers, lakes and atmosphere (Drengson and Taylor, 1997). Research in Kenya (Lind and Morrison, 1974), Tanzania (Pocs, 1973 and 1994) and South America (Gradstein et al, 2000), have shown that vegetation is an important catchment delivering as much as 2000 mm of water from mist. In Kenya, vegetation was found to be a water catchment for light showers and dew in dry lands. i.e. Maasai land, the north frontier districts and in maize field at Muguga. Pastures that are not grazed were more effective catchments than the gazed pastures in trapping light showers and dew due to their large surface area. The mist forests are consistently subjected to light showers, mist, and dew formation caused by temperature inversion. Dew is known to deliver up to 2mm of rainfall per day (Bruinjell, 2005).
Globally there is increased vegetation loss, accompanied by general water stress as global temperature increases. In Kenya over 4.5 million people were exposed to increased water stress in the national drought of 2008 (NCCN, 2010). In Uluguru Mountains, forest zones deprived of cover evaporated four times more than forested parts and recorded higher temperature as compared to area under forest cover (Pocs, 1973). This imply that vegetation have an important role in terrestrial and probably global temperature control.
On Mt. Kilimanjaro, the effects of forest cover loss due to conversion of natural forest to plantation forest, results to drier micro-climate within the forest and a reduction in diversity of micro habitat caused loss of 90% of forest species bryophytes (Pocs, 1973). This suggests that the tree species and vegetation type is an important factor in water catchment and conservation. Bryophytes are good indicators of forest environmental conditions due to their poikilohydric nature. Some bryophytes species such as epiphylls specialize on a consistently wet leaf lamina are found in wet forest where dry period is short or nonexistent (Richard 1984).The specialist types of bryophytes lose habitat when forest microclimate are modified (Hallingback and Hodgett, 2000), This suggest that different species have differing adaptations to moisture levels and ability in trapping mist water.
In arid land with sparse vegetation, there is considerable surface run off in contrast to accumulation of water below the individual plant (Gwynne, 1962 in Lind and Morrison, 1974), showed that, the depth of penetration of rain water below plant is approximately equal to height of the vegetation. Therefore light-grazed grasslands penetrate more water than the heavily grazed grassland.
According to Queensborough, *et al*., (2007) the abiotic factors that potentially influence species coexistence and distribution include water availability, soil chemistry, topography and light availability, Plant species show significant positive associations with topography e.g. Ridges, valleys, slopes where local topography had subtle

effects on growth rate. Water and mineral nutrients availability influences on plants growth are hard to disentangle, because mineral nutrient availability are correlated with topography, with topography influencing water availability and soil chemistry.

The forest top canopy receives the full force of weather. The lower canopies serve to modify physical parameters as they filter through the forest canopies to the soil. According to Drengson and Taylor, (1997), the dominating tree species for the forest canopy have a major influence on the micro-climate, soil and water below and therefore strongly determine the forest health and productivity. The vegetation type is therefore an expression of resources available to plants for growth, the delicate balance between species and climate and species interconnections is observed in ecotones, where critical balance exist between the ecosystems characterized by high species diversity, and minor changes in climate can cause replacements (Camp, 1997). According to Lind & Morrison (1974), the growth habits of *Chryosopogon Spp.* grass of north and north eastern Kenya form an important catchment in light showers to the advantage of plant community. With efficient plants catchment, dew formation at night can deposit 0.1mm – 1.0 mm (rainfall equivalent) per night, while fog (mist) drip deposit on vegetation and other obstacles as much as 4mm of rain per hour (Bruinjeel, 2005). The fog also referred to as horizontal precipitation is water in form of clouds, carried by wind and normally above condensation level which when near the ground is referred to as mist, measured in term of visibility and humidity. Due to its nature of moving horizontally, the resource must meet a vertical block, so as to trap the water, otherwise it is carried away by wind. Netting barriers have trapped as much as 1 liter of water per m^2per day from mist in Atacama Desert (Araya and Espejo, 1999).

The economic valuation techniques and the scientific endeavors have been unable to appreciate the effects of the forests as catchments and its ripple effects on other ecosystems (Earth watch pg 134). The actual contribution of the forest vegetation in water cycle is not clear and the climate moderating effects such as heat absorbing effects that accompany the water catchment process and photosynthesis is ignored as vital role of forest in climate moderation. The interactions among niche axes such as water and soil nutrients availability, their relationship to topography and synergistic role of forests, and bryophytes as water catchments deserve further investigations.

The synergistic effects of mist trapping by vegetation, and the consequent ripple effects on climate change with reference to heat sinking is yet to be described by science. The objective of this research was to assess the mist trapping ability of pendant bryophytes and tree branch stems in Mt. Marsabit forest.

Research questions were;

1. What is the contribution of the pendant Meteorianceae (*Pilotrichella ampulacea* and *Frullania angulata*) bryophytes in mist water trapping in Mt Marsabit forest?
2. What role do stems and branches play in mist water trapping in Mt. Marsabit forest?

MATERIALS AND METHODS

Study site

Mount Marsabit is located on the northern part of Kenya, 560 km North of Nairobi, between latitude 2° to 3°N and longitude 37°E to 38°E, and raises from 900m asl to 1750 m asl; The forest covers 15,280 Ha, a green island surrounded by semi arid area (Gacanja *et al.,* 2001) and deserts of Kaisut, Dida Galgalu and Chalbi.

The vegetation starts as a dry open forest, and gradually changes to a tropical rain forest at the peak; where it ends abruptly without an ecotone into dry scrub type on leeward parts of the mountain. Numerous pendant bryophytes dominated the epiphytic vegetation on the wind ward part of the mountain.

The rainfall is under the influence of the Inter Tropical Convergence Zone (ITCZ), with the rain bearing clouds originating from East, to receive 1000 mm of rainfall per year (Gacanja *et al* 2001), with two dry seasons in a year, that are three months long. Mist is a consistent occurrence throughout the year and a daily and day long occurrence in July and August. Mt Marsabit forest is the water catchments area for 36,000 people, numerous domestic animals and wild life. It stands as an oasis within arid and semi arid lands. On the mountain, there are two crater lakes, Paradise and Sokote. (Marsabit means the cool place of the clouds in local dialect). The threat to flora is serious due to human encroachment for settlements, trampling by livestock and general habitat degradation. This study was conducted in dry months of January, February, June and July which receives lowest rainfall. The study site is shown in Figure 1.

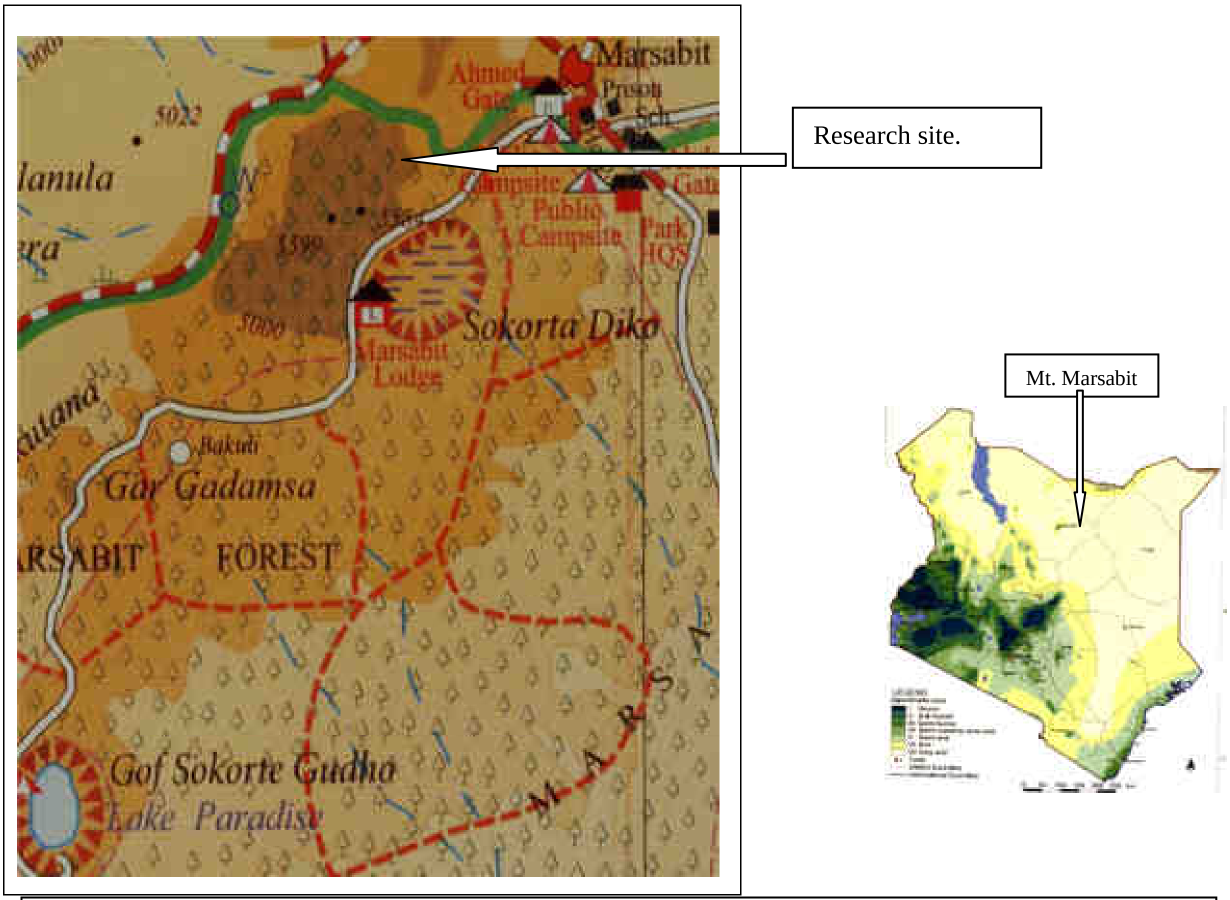

Fig. 1: Map of part of Marsabit National Park / Forest showing the location of the research site. Mt. Marsabit forest is in the midst of arid region of northern Kenya.

Vegetation survey

The change of bryophyte and vegetation was assessed using transects running from wind ward side to leeward side. A second transect run from Karare (south) to through the mountain peaks to lowlands (north) of Goff Chopa. The location of the bryophytes on the trees and other substrates was noted.

Bryophytes water retention capacity assessment

To assess water retention capacity of Meteoriaceae and *Frullania angulata* bryophytes, naturally occurring mats of varied weights were harvested in plastic bags and weighed. The mats of Meteoriaceae and *Frullania angulata* were placed on mesh wire and sprayed with water for 30 minutes, then allowed to drip until dripping stopped, the mats were then weighed. The mats were oven dried at 42 ^{0}C for 4 days, and the dry weight was taken when hot.

Bryophytes hygroscopic capacity assessment

The hygroscopic capacity of Frullania angulata and Meteoriaceae bryophytes was assessed. The bryophytes were harvested in paper bags and taken to laboratory and oven dried. The bryophytes were mats to the laboratory, oven dried at 80^0 C for 4 days, and then weighed hot. Thereafter, the mats were then put in open trays and the tray placed on a bench in a room at 20^0 C and relative humidity of 70% for 4 days, and then reweighed.

Bryophytes mist trapping assessment

To assess bryophytes mist trapping ability, 300 g of bryophytes were mounted and sandwiched between 2 wire mesh of 6 cm x 6 cm mesh size on the mist trap that measured 50 cm x 50 cm. The reservoir was capped. A 2 cm wide gutter for collecting drip water from of bryophytes was inserted through the reservoir cap. 28 mist traps were set up to study mist trapping extent of the bryophytes (See Fig. 1 and 2).

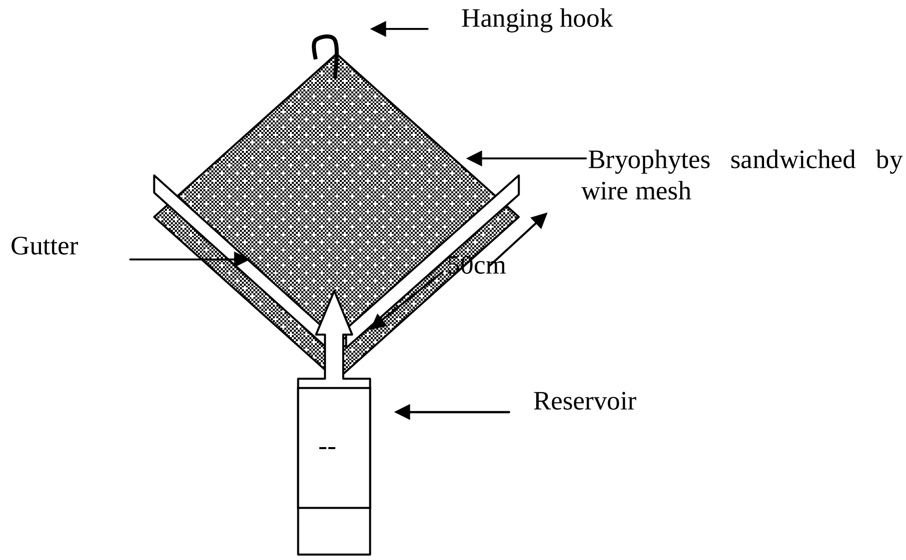

Fig., 3: Design of the mist trap showing two gutters draining into the water reservoir.

Plate 1: Bryophytes mounted mist traps on top the hill overlooking Ahmed gate of Mt Marsabit forest reserve.

Stem simulates mist trapping ability assessment

To assess mist trapping ability of stems and branches, 12 logs simulates of 20 cm, 35 cm and 53 cm circumferences all 50 cm long, were dressed with 300 g of Meteoriaceae, the moss was held to the logs using wire mesh of 6 cm x 6 cm-mesh size. The logs were placed on the same platform 1.2 m above the ground at 1450 m asl. A plastic gutter was tied at the base of each log with to direct collect water to reservoir.

RESULTS

Vegetation survey

The vegetation on Mt. Marsabit forest occured in small communities dominated by different species, i.e. *Croton megalocarpus, Croton dichogamous, Croton microstachyus, Olea europaea spp africana, Vangueria madagascariensis, Strychnos henningsii, Piliostigma thonningii, (Bauhinia thonningii), Dovyalis abysinica*, *Trichilia emetica*, among others. The forest trees on leeward and the peak has an extensive cover of pendant Meteoriaceae bryophytes. When there was no vertical precipitation at all, the research site was slippery to walk on due to mist water dripping from the trees and pendant bryophytes in the forest. On the leeward parts of the forest, overlooking Parkishon and Hulahula, the trees were heavily laden with lichen, *Usnea sp.* The *Usnea sp.* lichen was absent on the windward side. On some trees both *Usnea sp*. and Meteoriaceae appear but bryophytes were on the windward side and *Usnea sp.* on the leeward side. Healthy trees had a lot of luxuriant and extensive bryophyte cover in contrast to dying and dead trees whose bryophyte cover was scanty. During mist the trees were wetted on the leeward side and completely dry on the leeward side (Fig 4).

Fig 4: *Olea europea ssp africana* dripping wet on windward side and dry on leeward side in Mt. Marsabit

On misty days, water would trickle down the boughs of trees, causing a surface runoff, 50 m. long on relatively dry ground (Fig 5). The ground wetting was pronounced on ground under trees. In open places without vegetation cover, the soil remained dry or superficially wetted during heavy mist (Fig 6).

Fig 5: *Tristernia conferta* tree by the road side, trapped mist water in one morning and generated 50 meters long stream of surface runoff.

Dry areas in open patches

Wet area under tree canopy

Fig 6: The effect of tree canopy on mist trapping showing the origin of the surface run off and dry patch beyond.

Bryophytes water retention capacity

The mean mat weight of dry *Frullania angulata* was 19.35g, with water retention of 5.21g (ml) per gram of bryophytes. Meteoriaceae bryophytes had retention capacity of 5.14 g (ml) of water per gram of bryophytes. The retention capacity of both Meteoriaceae and *Frullania angulata* bryophytes was more than 600 % of their own dry weight (Table 1).

Table 1: Water retention capacity of *Frullania angulata* and Meteoriaceae.

	Harvest Wt.(g)	After drip Wt. (g)	Dry Wt. (g)	% wt. change
Meteoriaceae Mean (19 samples)	60.36	347.31	56.52	614.43
Frullania angulata Mean (28 samples)	21.92	120.21	19.35	620

Bryophytes hygroscopic capacity assessment

The hygroscopic capacity of bryophytes was more than 13 % of own dry weight at RH of 70 % (Table 2). This implies to that bryophytes have affinity for water in the atmosphere that may be more effective in the clouds when RH is 100 %.

Table 2: Hygroscopic capacity of *Frullania angulata* and Family Meteoriaceae bryophytes

	Harvest Wt (g)	Dry Wt (g)	Wt gain (g)	% Wt. change
Meteoriaceae	330	223	252	13.9
Frullania angulata	300	208	237	13.0

Bryophytes and mist trapping assessment

The Meteoriaceae mounted mist trap intercepted and installed in the reservoirs an overall mean of 177.3 ml of water using an area of 0.25 m^2 per mist day, equivalent to 709.3ml per m^2 per mist day. In the month of February the mean water trapped per mist water installed in the reservoir was 1293.68 ml per m^2 per mist day (Table 4); translating to 42mm of rainfall annually and 3.5mm of rainfall in February. Working with the observed mist frequency of 1day per week during the dry periods, the rainfall equivalent in mm was calculated.

The Meteoriaceae mounted mist trap intercepted and installed in the reservoirs an average of 709.3ml of water per m^2 per mist day; equivalent to 23.2mm of rainfall for the two months. In the month of February the mean water trapped per mist water installed in the reservoir was 1293.68 ml per m^2 per mist day (Table 4); translating to 42mm of rainfall and 4.09 mm of rainfall in June. Working with the observed mist frequency of 1day per week during the dry periods, the rainfall equivalent in mm was calculated.

Table 4: Mist trapping data by Meteoriaceae bryophytes in February and June

Mist days	Mean water trapped per trap / mist day (ml)			Water trapped / m^2 / mist day (ml)			Rainfall equivalent (mm / yr^1)		
	Feb.	June	Control	Feb.	June	Control	Feb.	June	Control
Mean	323.42	31.25	46.0	1293.68	125.0	184.0	42.445	4.09	6.035

The stem simulates mist water trapping ability assessment

The stem simulates of surface area of 0.05 m^2, 0.08 m^2 and 0.13 m^2 to trapped equal volume of 690ml per m^2 per mist day (Table 5, Fig 8 and 9); translating to 19mm of rainfall annually. The tree stems had mist water catchment ability of 7mm of rainfall annually. The mist water catchment ability of vegetation was inversely proportional to surface area of the vegetation (Fig 7).

Table 5: The mist water trapped by stem simulates with varying area per mist day converted to rainfall equivalent.

A (cm)	B (m^2)	C (m^2)	D (ml)		E (ml / m^2)		F (mm) yr^1	
			Largest	Mean	Largest	Mean	Largest	Mean
20	0.05	20.0	80	34.8	1600	690	52.52	19.12
35	0.0875	11.43	80	31.5	914	360.0	30.00	9.7
53	0.13	7.69	80	33.8	632.1	253.7	20.18	7.8

Key

A; Circumference of stem simulates experiments and controls. B; Actual area used by the stem simulates to trap mist. C; Conversion factor to actual surface area used to trap mist in m^2. D; Largest and mean quantities of mist water trapped by stem simulate. E; Total mist water collected by m^2 of stem simulates. F; Volume of mist water trapped by stem simulates experiments equated to rainfall in mm.

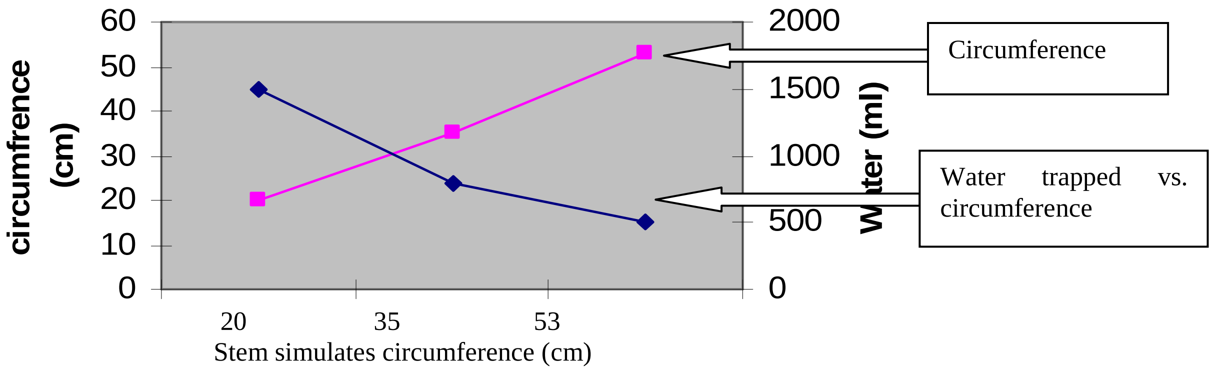

Fig. 7: Comparison between stem simulates circumference and mist water trapped.

Conversion of water trapped (ml) to rainfall equivalent (mm).

A standard rain gauge collects 100 ml of water when 8 mm of rainfall is recorded using the rain gauge area is 126.729 cm ^{2}. The mist water trapped was expressed in ml / m ^{2}, while the rate of mist occurrence on the study site was once a week (52 weeks per year).

Therefore;

$$\text{Annual Rainfall equivalent} = \frac{\text{Volume of water trapped per m}^2}{\text{Area of rain gauge}} \times 8 / 100 \times 52.$$

The water collected in the reservoir of the mist trap was the excess water dripping after bryophytes retained 6 times their own dry weight (Fig 9, 10 and 11). The stem simulate with circumference of 20cm trapped 3 times more mist water than stem simulate with circumference of 53 cm (Fig 7). This supports the large surface being a more effective mist water catchment. In all Meteoriaceae mist traps; there was a significant difference between the experiment and the control with the control trapping more water than the experiment. However, when retention is factored in, the mist water trapped by the control was 0.14 of the water trapped by Meteoriaceae. But *Frullania angulata* experiments and control trapped equal quantities of water, implying that *Frullania angulata* was less effective catchment when compared to Meteoriaceae.

This implies small size branches trap more water than large stems suggesting that the leafy part of the forest canopy was more effective catchment in trapping mist water than other parts of vegetation.

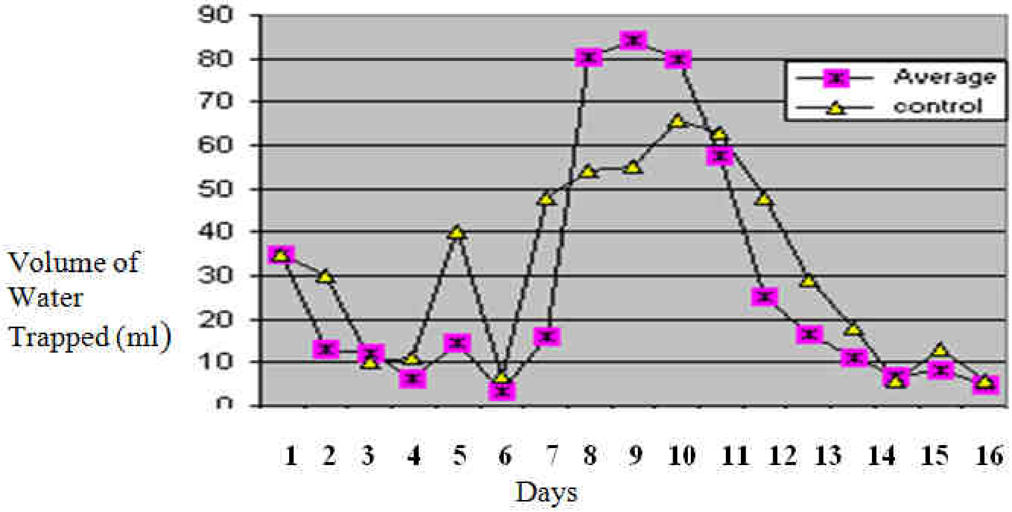

Fig 8: Comparison of average of mist water trapped by stem simulates and controls.

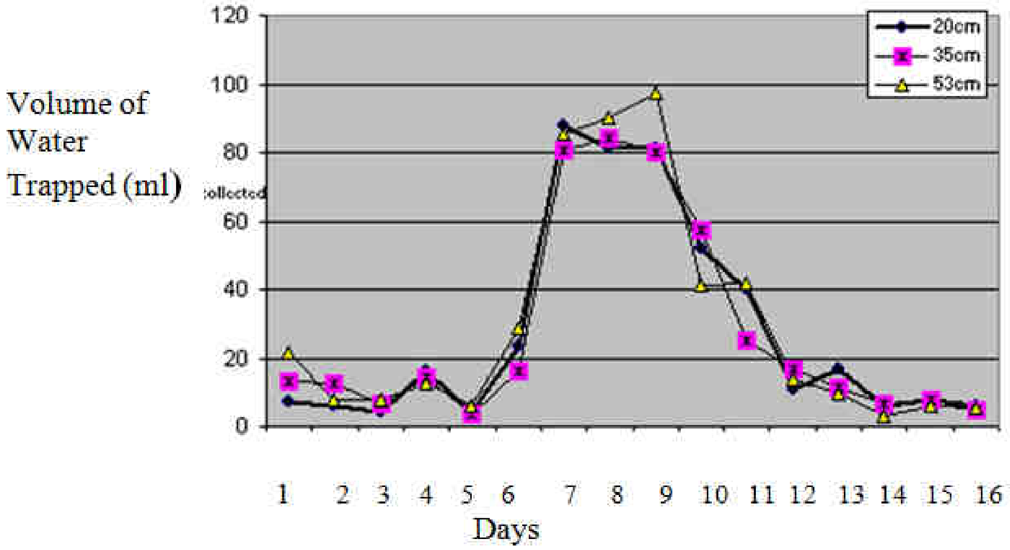

Fig 9: Comparison of mist water trapping ability of stem simulates of 20cm, 35cm and 53 cm circumference.

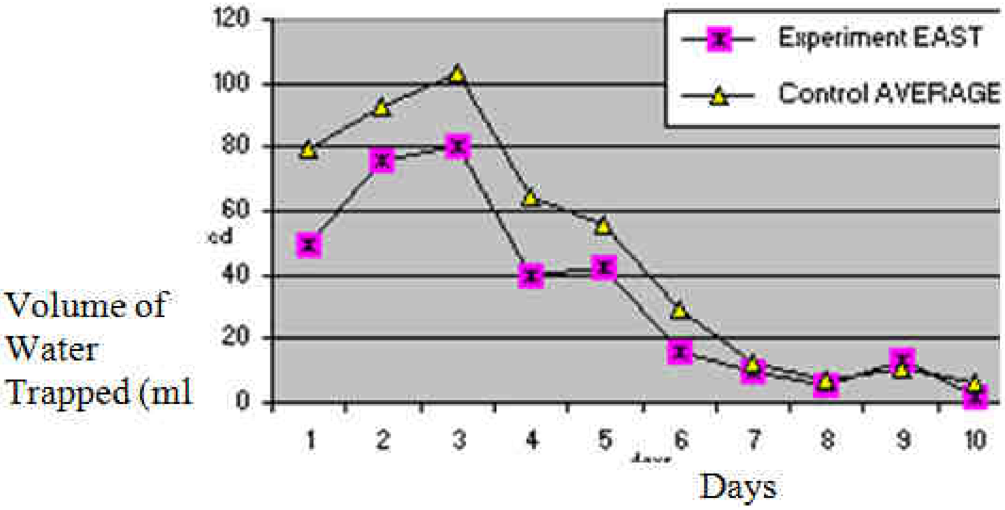

Fig. 10: Comparison of mist water trapping ability of East facing mist Meteoriaceae trap with control (mean).

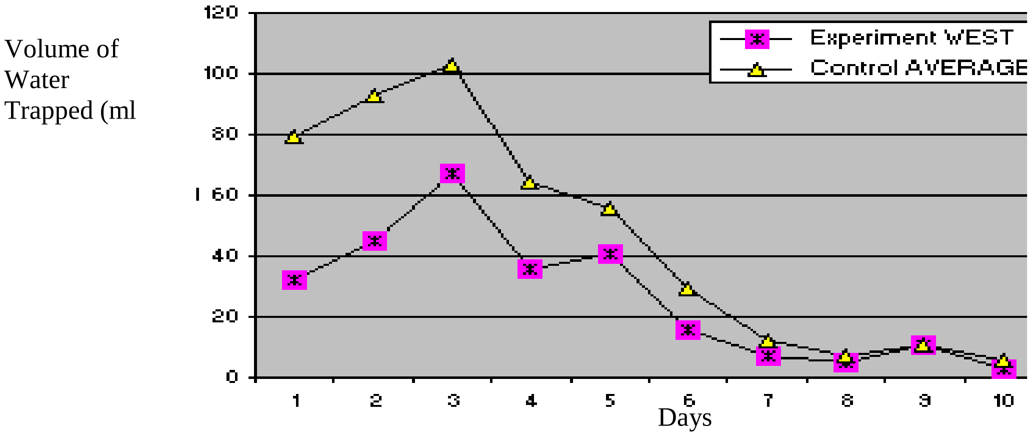

Fig.11: Comparison of mist water trapping ability of West facing mist trap with control (mean).

DISCUSION

Vegetation and mist water catchment

The vegetation on Mt. Marsabit forest is a water catchment that intercept and avail to the forest ecosystem more than 300mm of extra water from mist, over and above the 1000mm of rainfall received annually and measured by rain gauge (Tables 4 and 5). This extra water was available to the parts of ecosystem covered by vegetation. The volume of mist water trapped is directly proportional to surface area of the vegetation (Table 7); making the thick forest more efficient in mist water trapping. The evidence of large surface area is reinforced by stem simulates experiments (Table 5 and Fig. 7), where simulates of 53 cm circumference, using 0.13 m^2 surface area and a branch simulates using an area of 0.05m trapped equal amount of water.

The height of trees in forest increases with altitude while the forest changes from an open forest at 900m asl to 3 canopy forest at the peak. It appears that the vegetation creates proportionate synergistic effects on mist water trapping and forest growth. The bryophytes have extensive surface due to their small size and numerous leaves making bryophytes more efficient in mist water trapping than other plants. Considering that only a fraction of the forest surface area (stems) was used for this study, the total volume of mist water trapped by forest vegetation availed to the forest ecosystem is more than 1000mm of rainfall received annually. The total rainfall received annually from both rain and mist on Mt. Marsabit forest is over 2000mm.

This research confirms that vegetation on Mt. Marsabit forest is an important catchment than previously appreciated (Tables 4 and 5); and that mist is a resource that Mt. Marsabit forest ecosystem have utilized to maintain it tropical forest type of luxuriance in the midst the desert.

The role of trapping of the mist water by vegetation is supported by the following findings and observations; Firstly, epiphyll were collected on Mt. Marsabit forest during the 4 months long dry (rainfall deficient) season, confirming the wet status of forest during the dry months. Secondly, the tree stems were wetted by the mist on the wind ward side while the leeward side was completely dry. Thirdly, the bryophytes mats and the pendant

Pilotrichella spp. were growing on the wind ward side of trees, suggesting wind borne rain (Horizontal precipitation) or mist as the principle form of precipitation. The bryophytes mats were heavy with water in misty conditions. The weight of the water trapped by bryophytes would make the mats cut and fall off to litter the forest floor. Fourthly, on the north eastern slope of Mt. Marsabit, 1000 m asl, a 50 meters long water surface run off formed on a on a dry road after trickling down the trunk of *Tristernia conferta* during mist condition when there was no rain at all. (Trapping of mist water trickling down the stems *Eucalyptus* trees, is an important source of water for domestic use, on the stream less Hurri hills, 70 km west of Mt. Marsabit).

The change of vegetation on Mt. Marsabit forest is gradual on the windward side, from scrubland to a three canopy Tropical Rain Forest at the peak, but ends abruptly without an ecotone to a dry scrub type of vegetation on the leeward side of the forest. The change in the forest vegetation suggest increasing availability of mist water resource with altitude.The luxuriance of the vegetation cannot be justified be justified by1000mm of rainfall annually received on the mountain. The rainfall alone cannot explain the sharp transitional boundary of ecosystem change. This leeward effect is also observed on mountains; Uluguru (Pocs, 1973), Kenya (Bussman 1994), Kilimanjaro Pocs, (IUCN) and (Kemp, 2002). Finally, the location of permanent springs less than 100m from the peak, suggest consistent aquifer recharge. The occurrence of mist on the mountain is consistent throughout the year. The rainfall brief and seasonal rainfall and cannot therefore be the means for replenishment of the springs.

The implication of vegetation loss is primarily, the loss of catchments surface for mist water and reduced water resource. The secondary effect of vegetation loss is reduction in mulching effects of the forest cover that conserve the harvested water to create a wetter and humid forest microclimate. According to Pocs (1973) cleared parts of forest evaporates four times as much as the area under vegetation.

This explains for the sudden change of Mt. Marsabit Tropical Forest to scrubland just past the peak on the leeward side. The typical forest and tree structure have more surface area on the twigs than branch stems. This means that more mist water was trapped by twigs in the forest compared to branch stems. This view is supported by mist traps trapped more water than stem simulates (lit. rev.).

The dominant trees species in Mt. Marsabit forest were mainly trees with large crowns and branches spreading at an angle of more than 45° to horizontal of the branch base. For example, *Ficus spp., Olea europaea ssp. africana, Croton megalocarpus, Prunus africana, Diospyros sp., Strychnos henningsii, Strychnos mitis, Trichilia emetica,* among others. These types of trees appear to be favored by misty climate in Mt. Marsabit forest, possibly because of the tree ability to trap mist water and direct the mist water to the base of the tree.

Vegetation as water catchment and bryophytes

Loss of vegetation means loss water catchments and reduced mulch effect both of which accelerate rate of drying (Pocs, 1973). The positive synergy that vegetation creates works negatively when vegetation cover is lost. This explains for the sudden change of Mt. Marsabit Tropical Forest to scrubland just past the peak on the leeward side. The results of the stem simulates evidence of large surface area is more efficient. (Compare stem simulates of 53 cm circumference, using 0.13 m^2 surface area and a branch simulates using an area of 0.05m trapped equal amount of water).

Bryophytes water retention capacity

The high water retention capacity of bryophytes (Table 1) can be explained by several features on the bryophytes. Firstly, the bryophytes lack of cuticle, therefore exposing the hydrophilic bio-chemicals the pure water in the air (mist). The concentration gradient between the atmospheric mist water and water adsorbed in bryophytes, cannot be bridged because pure mist water becomes impure on touching the bryophytes, causing continuous mist water attraction to the bryophytes (Salisburry and Ross, 2001). The electro-statically charged hair points attract the polar water droplets from the mist (Hallingback and Hodgett, 2000). In addition, **Bryophytes have hygroscopic capacity of** 13 % of its own dry weight (Table 2), which is an additional force that assists bryophytes to attract and harvest water from humid air.

The ability of Bryophytes to trap mist water was over 7,000 ml of mist water was trapped by a 1 m² surface area. The experiments using bryophytes and stem simulates showed that Mt. Marsabit forest vegetation is a water catchment for mist water equivalent to 300 mm of rainfall, over and above the 1000mm measured by rain gauge (Table 4). This explains the rush vegetation on the windward parts of Mt. Marsabit forest (Fig.8, 9 and 10). The bryophytes mist traps experiments trapped 1000 ml of mist water per m² per mist day, equivalent to 65 mm of rainfall per year. The 1000 ml of water (65 mm rainfall equivalent) falls to the ground as excess, while 6,000 ml (196 mm rainfall equivalent) are retained by the bryophytes (See water retention capacity), and thereafter, gradually released to environment as drip and evaporation.

Stem simulates mist water trapping ability (Table 5 and fig. 7), show that the stem simulates trapped 600 mls per of water of mist water per mist day using m² area, translating to 52 mm of rainfall per year by tree branches (Table 5). Mt. Marsabit forest therefore, receives more water than documented because the leaves and twigs have more extensive surface area than branches and stems.

Vegetation, mist water and climate change Loss of vegetation in cloud forest results to reduction of water resource that the ecosystem had been receiving and using in maintenance of its dynamics, in direct proportion to surface area lost. The water absorbed cools the ecosystem and accelerates carbon dioxide fixation in the same proportions. Water absorbs the heat on earth surface and resists increase in ambient temperature of terrestrial ecosystem at the rate of specific heat capacity of different states of water. Vegetation loss marks the initial stage in a positive feedback mechanism with adverse ripple effects on climate changes. Trees attract "rain" by trapping horizontal precipitation. The climate moderating role of vegetation and terrestrial ecosystem thermo-regulation and heat sinking may be far more important than previously appreciated. The link between biota and physical climate is photosynthesis. In the forest trees form vertical barriers with large surface area that trap more mist water than shrubs, bushes and grasses. In absence of vertically standing physical tree blocks, the mist deposits nothing in the area. The effect of clearing forest is negatively synergetic and accelerated rate of drying (Pocs, 1973). While the shading effect of trees is reduced resulting to faster rate of water loss. Most streams in the mist forest could be maintained by of surfaces run off from trees trapped from horizontal precipitation.

Loss of mist water catchment and climate change

Water accelerates plant growth by mobilizing nutrients, encouraging soil formation and maturation processes. The mist water trapped by the vegetation changes the climate in the forest by; increasing the level of water resource and conservation of moisture. The ripple effect are; reduced ambient temperature, decreased soil temperature, reduced the drying effect of wind, moisture conservation by vegetation and reduce solar radiation as vegetation absorbs light and heat for photosynthesis. The overall effects of the vegetation in the forest are, increased moisture index in the forest and reduced temperature. This discourages evapo-transpiration in inverse proportion to number of mist days, mist duration, intensity and vegetation covers.

The cooling effect of dew and mist water in ecosystem becomes apparent when latent heat capacity of different states of water is considered.

The latent heat capacity and specific heat capacity of vaporization of water are 4200kj/ liter for 1^0 Celsius, and 2260Kj/liter, respectively. The ambient temperature of Mt. Marsabit forest was 19^0 C. To Estimate the dew point the formula below was used;

Dew point = Ambient temperature – (100 - Relative Humidity /5.) + 2.5^0C.

In misty conditions the relative humidity was 100%. Therefore, the dew point temperature was 22.5^0C. At RH of 80%, the dew point was 18.5^0C, While the dew point temperature was15.5^0 C at RH of 65%. At RH of 50% the dew point is11.5^0 C. The implication is that when humidity is low the mist water trapped has more cooling effect on the earth surface due to the large temperature difference between the dew water and ambient temperature.

Referring to mist trapping ability of vegetation, on a misty day in Mt. Marsabit forest ecosystem, a m^2 of bryophytes trap 7000 mls of mist water which absorb over 51,680kj of heat form ecosystem per mist day. For every liter of mist water added to the ecosystem, over 6460kj of heat is absorbed when temperature changes by 1^0C and thereafter evaporates from vegetation and the earth surface. The dew point (mist) temperature is few degrees lower than the ambient temperature when humidity is low. The sun delivers energy to the earth surface at an average rate of 4.3 x 10^{20} j/ hr^{-1} (Chuanhao *et al.*, 2010), which is used for heating the bare ground, and for photosynthesis in forested parts of the earth. The conversion rate of the suns energy to organic matter by vegetation is at a rate of 60 quanta of blue light for each glucose molecule fixed (Salisburry and Ross, 2000). The energy absorbed by vegetation is expressed as absorption spectrum and action spectrum are more active within the heating range of the visible light spectrum. Increased vegetation means more chlorophyll, more CO_2 fixation (higher productivity) and heat sinking. This is supported by research findings by Pocs (1981) in Kilimanjaro, where bare forest parts recorded higher temperature than forest, and dried four times faster than forest. Increase of CO_2 level in the atmosphere is global and attributed to vegetation loss (lit. rev.) implies decrease in heat sinking process. The cooling (heat sinking effect) of the vegetation, through mist or dew catchment and photosynthesis is beyond the forest boundaries and a contribution to climate change. The link between CO_2 levels in atmosphere, global warming, and change in climate is photosynthesis through water cycle. This makes vegetation the thermo-regulating organs for the earth surface. The naked earth have increased temperature, that encourage generation of heat waves and faster wind currents, that causes further drying. In Kenya, the country annual average temperature, have increased by 2^0 C (NCCS, 2010). This may be explained by progressive vegetation loss on protected highland forests (Bussman, 1994) but more critically, the unprotected rangelands that constitute 83% of Kenya land surface.

Conclusion

The additional 300 mm of water resource availed to the forest ecosystem, explains the increase in vegetation luxuriance with altitude windward side and lack of ecotone on the leeward side of mount Marsabit. The additional 300 mm of rainfall is only available where there is vegetation. The efficiency of the vegetation as a catchment for mist water increases with the surface area of the vegetation. Mist is the compensation factor that supports this forest ecosystem, while the vegetation is important water catchments for mist water. It is clear that the role of the vegetation on the water cycle, local climate moderation and climate change is more than currently

appreciated by science.
The bryophytes have an surface area larger than other plants, that combine with high water retention capacity 600%, hygroscopic capacity of 13% own dry weight and insatiable affinity for mist water to have a unique role in mist forest.
The fact that bryophytes colonize inhospitable habitats as pioneer community makes them special catchment with ability and unique role. The primary effect of vegetation loss is loss of the extra water for the plant community. The ripple effects of catchment loss are interrupted hydrologic cycle, reduced vegetation growth and recovery and heat sink. Mist water trapping makes the vegetation to thermo-regulate and resist adverse changes in climate, hotter Earth and accelerated climatic changes towards desertification. The thermo-regulating effect of vegetation on the earth surface makes vegetation critical in management of the effects of climate change.
Mt. Marsabit forest receives 1000mm of rainfall annually and additional 300 mm of rainfall equivalent trapped from mist by vegetation and availed to ecosystem.

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