# Groundwater and the ecology of *Avicennia marina* (Forsk.)Vierh. and *Rhizophora mucronata* Lam. in Kenya

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## Introduction

Mangrove ecosystems are composed of as well terrestrial elements as marine elements. It is this duality that makes the mangrove forest a unique ecosystem with a very high ecological and economical value for the tropical and subtropical coastal zones and their inhabitants.
Ecologically, the mangrove forest can be considered as a nursery for many marine species like fishes, crabs, prawns, molluscs. Many bird species also search for shelter in the forest.
Because of their partly above-ground root system, mangroves filter land runoff, increase sedimentation rates, protect the land from erosion and trap toxic substances in the sediments.
Economically, the forest is very important for local communities that depend on the forest for fuelwood, charcoal, building poles (Kokwaro, 1985) and food (Saenger, 1983). Very recently the forest is also used as a site for human and industrial waste (Oteko, 1987).
Tack (1997) already showed a clear relation between the distribution of mangroves and the groundwater flow. In this study different parameters of the forest are investigated in places showing a difference in groundwater flow.

## Methodology

### Choice of the study sites

The study sites were chosen in function of the rough groundwater maps, having cells of 8 by 8 km. Fifteen mangrove forests or parts of it were selected showing a variation in groundwater flow, ranging from 2.03 to 6.57 $m^2.day^{-1}$. The studied mangrove areas with their predicted groundwater flow are given in table 1. Mangrove forests covering a big surface, like is the case in Mida, Kilifi and Mombasa, were splitted in different parts, according to the differences in predicted groundwater flow.

### Measuring different parameters

In every site the diversity was investigated using the point-centered-quarter method (Snedaker & Snedaker, 1984) on four transects. These transects were chosen in that

*Table 1. The study sites with their predicted groundwater flow, according to the model.*

| Study site | Groundwater flow ( $m^2.day^{-1}$) |
|---|---|
| Ngomeni | 6.57 |
| Mida 1 | 3.59 |
| Mida 2 | 4.00 |
| Mida 3 | 3.69 |
| Kilifi 1 | 2.54 |
| Kilifi 2 | 2.95 |
| Kilifi 3 | 4.29 |
| Mtwapa | 2.84 |
| Mombasa 1 (Tudor Creek) | 2.98 |
| Mombasa 2 (Tudor Creek) | 3.06 |
| Mombasa 3 (Port Reitz) | 2.03 |
| Gazi | 3.96 |
| Ramisi + Funzi | 3.73 |
| Shimoni | 3.49 |
| Vanga | 2.59 |

part of the forest, which showed the highest trees. Two species, namely *Avicennia marina* (Forsk.)Vierh. and *Rhizophora mucronata* Lam. were selected for further investigation, since they are the most abundant species. For the first species a distinction was made between the landward and the seaward zone. This because their differences in morphological aspects (De Bondt, 1995).

In a stroke of 25 m on either side of the transects all the *A. marina* and the *R. mucronata* were investigated. Their height was measured with a clipometre and the 25 highest trees in every division (*A. marina* seaside, *A. marina* landside, *R. mucronata*) were used to calculate the mean maximum height of the trees.

These 75 trees were also retained for investigation in number of propagules (in the case of *R. mucronata*) and the number of seeds (in the case of *A. marina*). The number of propagules and seeds were counted while still hanging on the mother tree and the value will be expressed in number per square metre tree.

### Statistical analysis

The relation between the groundwater flow and the measured parameters were analysed using the Spearman Rank and Kendall τ correlation coefficients.

## Results

Table 2 summarises the results of the non-parametric Spearman R and Kendall τ tests. Both, Spearman R and Kendall τ show a significant positive correlation between groundwater flow and mean maximum tree height as well as a significant negative correlation ($p<0.01$; $n=60$) between groundwater flow and the mean number of propagules. Those observations were done for *A. marina* on the seaside, on the landside and for *R. mucronata*.

The mean maximum height of *A. marina* (landside) doubles and that of the *A. marina* (seaside) triples, when the groundwater flow increases from 2.03 $m^2$. $day^{-1}$ to 6.57 $m^2$. $day^{-1}$. For *R. mucronata* we even suggest a curve close to the exponential curve. For a same increase in groundwater flow the heights varied from between 3 and 9 m at the lowest flow up to between 17 and 39 m at the highest flow.

Although no clear curve can be recognised when results of number of propagules of the *A. marina* are plotted, the correlation coefficients show a clear negative correlation. The number of propagules on *R. mucronata* show a logarithmic decrease with increasing groundwater flow, going from 49 to 70 propagules per $m^2$ tree in area with 2.03 $m^2$. $day^{-1}$ groundwater flow to 7 to 9 propagules propagules per $m^2$ tree in area with 6.57 $m^2$. $day^{-1}$ groundwater flow.

*Table 2. Spearman Rank and Kendall τ correlation coefficients between groundwater flow and the variables studied (n = 60). All results are significant (p<0.01).*

| Investigated variables | Spearman R | Kendall τ |
|---|---|---|
| Groundwater flow - Mean maximum height of *A. marina* (seaside) | 0.63 | 0.47 |
| Groundwater flow - Mean maximum height of *A. marina* (landside) | 0.81 | 0.65 |
| Groundwater flow - Mean maximum height of *R. mucronata* | 0.36 | 0.27 |
| Groundwater flow - Mean number of propagules. $m^{-2}$ of *A. marina* (seaside) | - 0.59 | - 0.45 |
| Groundwater flow - Mean number of propagules. $m^{-2}$ of *A. marina* (landside) | - 0.41 | - 0.30 |
| Groundwater flow - Mean number of propagules. $m^{-2}$ of *R. mucronata* | - 0.90 | - 0.74 |

## Discussion and conclusion

The coastal region of Kenya can be described as having a moderately high groundwater flow, ranging between 0.31 and 12.8 $m^2$. $day^{-1}$. Tack (1997) showed a clear relationship between the distribution of mangrove forests and the occurrence of groundwater. Mangrove forests are only found in areas with a groundwater flow higher than 1 $m^2$. $day^{-1}$. The actual study investigated the correlation between differences in morphological aspects and groundwater flow.

It was found that the maximum tree height decreased with a decreasing groundwater flow. However the three groups studied showed quantitatively a different response. This can be explained by the differences in physiological aspects of the different species. Mangroves are polyphyletique. All the trees evolved adaptations to survive in this saline environment., but they developed different strategies.

*R. mucronata* is a non-salt secreting plant. It survives in the inter-tidal environment by preventing the salt from entering the tree, by an efficient filter-system in the roots. Its poor efficiency to secrete salt may be a reason why *R. mucronata* shows an exponential increase in height, when groundwater flow increases.

Opposite to *R. mucronata* lays *A. marina*, a salt-secreting plant. The plant here allows the saltwater to enter the tree. The salt is then secreted by the leaves, which can easily be recognised as the white crystals usually found on the leaves. This might be the reason why *Avicennia* occurs in the higher parts of the forest, where, it is well-known, higher salinity concentrations occur, due to the evaporation of the undeep water. The secretion of salt allows a higher resistance to salinity. Therefore *A. marina* shows a much smaller increase in tree height than *R. mucronata*. Comparing the Avicennia of the seaside and the landside, a quantitative difference in response with increasing groundwater flow is observed. For a same increase in groundwater flow, the seaside *Avicennia* shows a more pronounced growth compared with the landside *Avicennia*.

The second parameter studied were the number of propagules, which showed a clear decrease with an increase in groundwater flow. Such a difference in strategy is usually related to a stressfactor, being here probably the absence or the low groundwater flow. Kairo (1995) and Verneirt (1994) showed a higher mortality of mangrove propagules in the more elevated parts of the mangrove area studied. This could mean that the survival rate of propagules increases with a decrease in salinity. The tree then can adopt a strategy of high or low number of propagules for respectively a low and high survival rate in an environment with a low and high groundwater flow.

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