The role of Vegetation and Water in cooling and stabilizing environmental extremities

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This article is a summary of the research paper "Trees, forests and water: cool insights for a hot world," by David Ellison, et al. It was published in Elsevier, available online on 9 February 2017. All illustrations, except when indicated otherwise, is sourced from this paper.

In this research it is revealed that forests and trees play a key role in regulating water, energy, and carbon cycles. The interactions between the sun's energy, forests and water form the base for cooling land surfaces, distribution of water resources throughout the water cycle components, as well as carbon storage as a valuable bonus.

Introduction

Several regions in the world, like Southern Africa experience water constraints as well as severe and prolonged droughts. The map in Figure 1 shows a global perspective on the regions that experience water scarcity.

Typically, in South Africa, rainfall occurs in a 4–5-month period, with the remainder of the year dry. During the growing season frequent hot dry spells as well as severe flooding can occur. Therefore, interventions that can mitigate these severe events should be investigated and implemented.

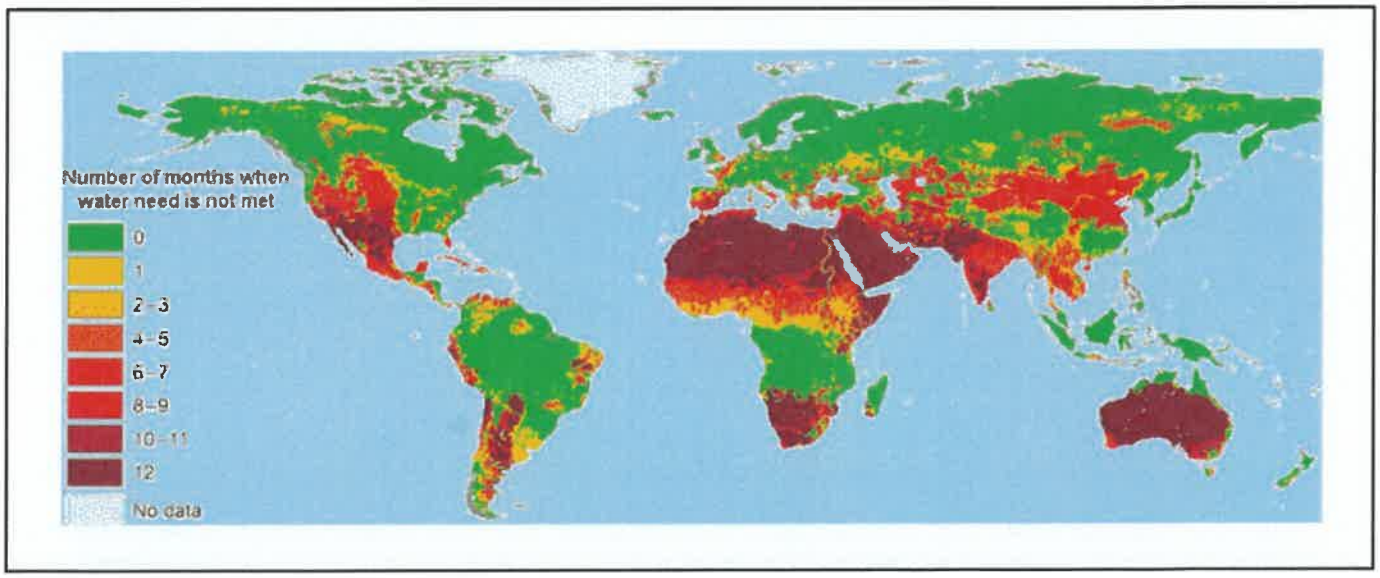

Figure 1: Drought areas of the Earth, (from M. M. Mekonnen and A. Y. Hoekstra, Four billion people facing severe water scarcity, *Science Advances, 2 (2016) e1500323)* http://www1.lsbu.ac.uk/water/water_phase_diagram.html#all

This article discusses the significant role that forests play in regulating global temperatures as well as production and maintenance of freshwater flow. Benefits of healthy forests include protection and intensification of the hydrological cycle, landscape cooling and carbon storage.

Through evapotranspiration trees recharge atmospheric moisture. This process provides a significant contribution to precipitation locally as well as regionally on the same continent. This depends mostly on the prevailing wind directions. The evapotranspiration process is driven by heat energy from the sun. This effectively results in cooling the environment. Therefore, any deforestation and land use patterns which cause deterioration or loss of vegetation have long term detrimental implications on the climate, ecosystem functionality, livelihoods, and survival of species. Currently changes in land cover could be responsible for up to 18% of global warming trends. Deforestation influences local temperature increases as well as rainfall.

Reforestation, done correctly and at the optimal locations, can have a positive influence on the water and energy cycles, as well as the availability of fresh water.

Relationship between forests, rainfall, and availability of water

Water vapour is released from the land and sea surfaces into the atmosphere. Forests and other vegetation play a crucial role in regulating fluxes of atmospheric moisture and rainfall patterns. This happens through evapotranspiration (ET) from soil and plant surfaces and transpiration of water by plants.

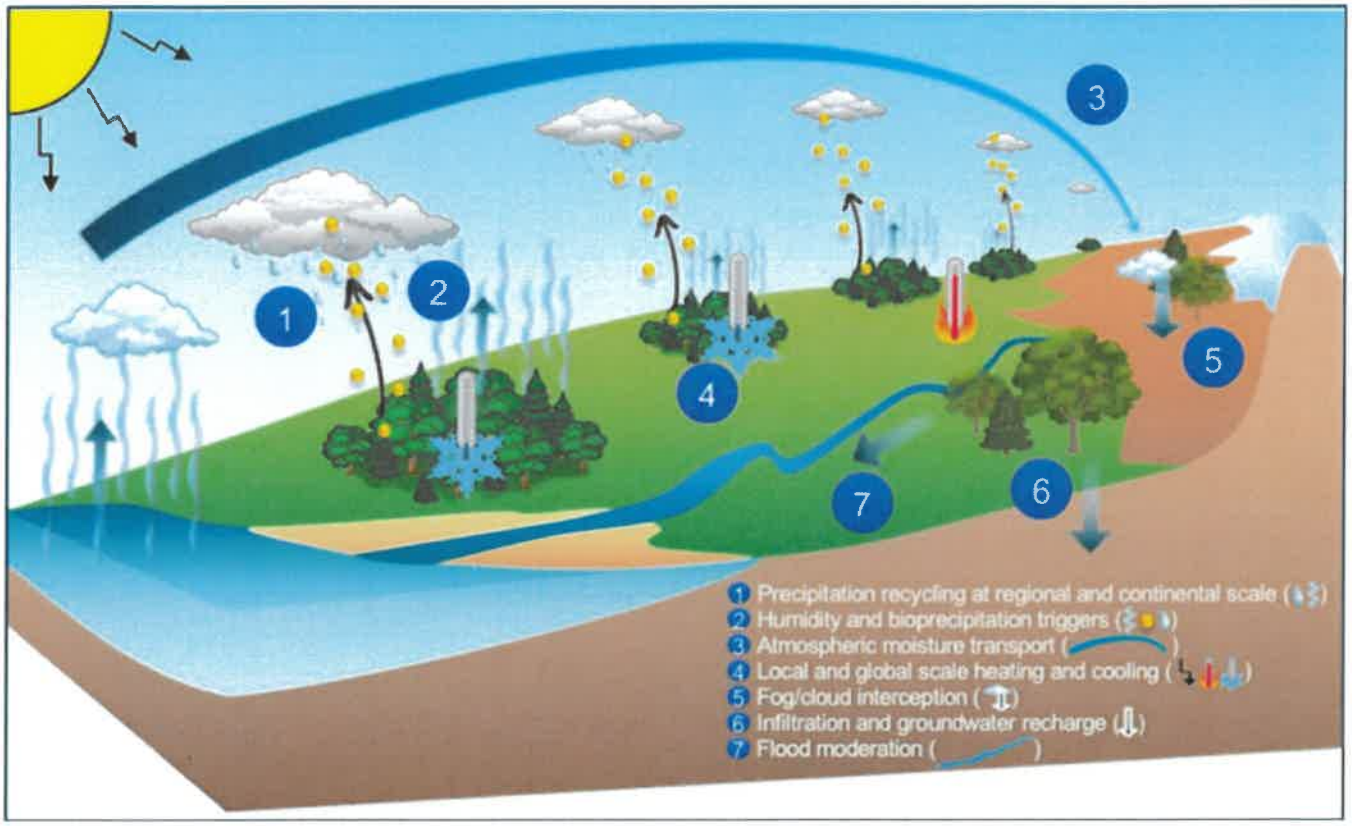

Fig 2. Effects of forests on local, regional, and continental water and climate characteristics through change in water and energy cycles. (1) Precipitation is recycled by forests and other forms of vegetation and transported to the interior of continents. (2) Upward fluxes of moisture, volatile organic compounds, and microbes from plant surfaces (yellow dots) create precipitation triggers. (3) Forest-driven air pressure patterns may move atmospheric moisture far inland. (4) Water fluxes cool temperatures and form clouds that shield land surfaces from solar radiation. (5) Fog and cloud interception by trees extract additional moisture from the atmosphere. (6) Infiltration and groundwater recharge can be facilitated by trees. (7) All of the above natural processes spread water, thereby moderating floods.

The atmospheric moisture obtained is eventually carried by winds across the earth. This could happen through "precipitation recycling" given conducive circumstances. Moisture coming overland from the ocean, forms precipitation, which partially becomes atmospheric moisture again through evaporation and evapotranspiration. By means of prevailing winds it could be carried further inland to repeat the process, thereby redistributing water across the continental surface. The contribution of evapotranspiration to overland rainfall is about 40% of the total.

Therefore, water availability in a local catchment area is influenced by the production through evapotranspiration and movement of atmospheric moisture from remote upwind areas, as described. Dense vegetation like forests produce more atmospheric moisture due to higher evapotranspiration rates than grasslands or deserts where vegetation is less dense or sporadic. The movement of moisture through the atmosphere and the effect that vegetation has on evapotranspiration implies that all or most catchments are naturally linked. Therefore, deforestation and land degradation reduce evapotranspiration, but the impact could be thousands of kilometres downwind.

Trees and forests release biological particles into the atmosphere, thereby increasing the potential number of particles around which atmospheric moisture could condense when there is sufficient moisture available. This could include fungal spores, pollen, bacterial cells, and biological debris.

How forests move water

Atmospheric moisture originating from evaporation from the sea and land surfaces, as well as evapotranspiration from vegetation are moved across the earth by means of the prevailing winds. Parts of continents that are further away downwind from coastal areas where moisture is blown over land by the prevailing winds, will most probably be affected the most by changed land atmosphere interactions where deforestation have occurred somewhere along the path of movement of the moisture. These areas could experience changes in the seasonal timing and feedback effects, as well as increased unpredictability of rainfall. In addition, the

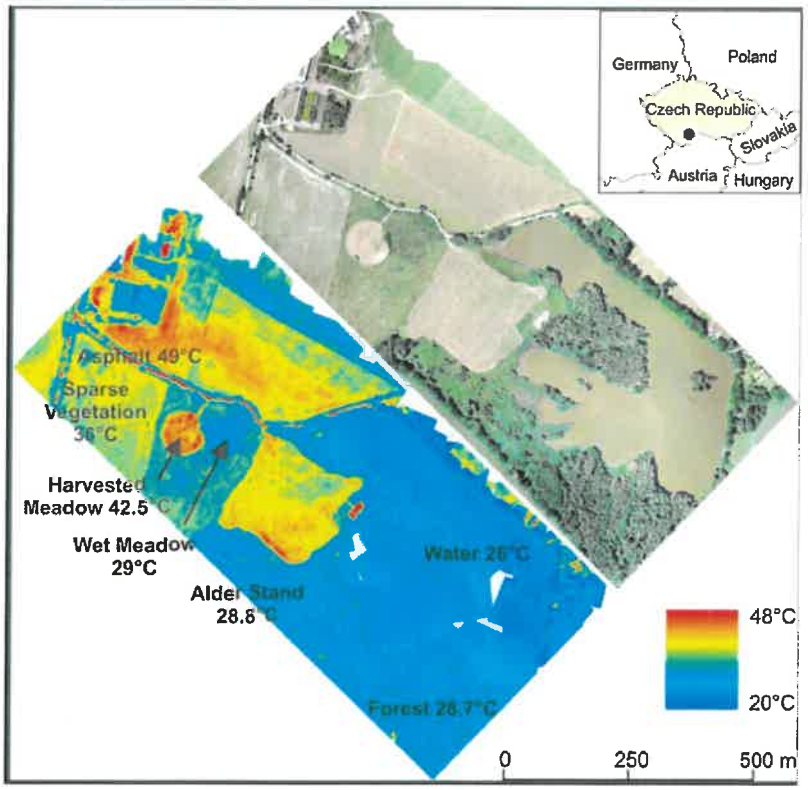

Fig. 3 Surface temperature distribution in a mixed landscape with forest. Source: adapted from (Hesslerová et al. 2013).

quantity, reliability, and extent of rainfall could be reduced. Deforestation may also cause changes in the wind patterns. The drying of the climate is the inevitable result.

Through reforestation on a large scale many of these negative impacts could possibly be reversed over time. The theory of "The Biotic pump effect" suggests that large forests extending inland from coasts might fulfil a significant role in the movement of moisture to continental inland areas.

Influence of vegetation and forests on the temperature

Forests and vegetation have an influence on heat flow dynamics and therefore on the temperature on earth. Due to shade and the fact that evaporation and evapotranspiration absorbs latent heat, sensible temperature is reduced. Therefore, locally in tropical and temperate regions, the earth's surface is cooled during daytime by forests and other dense vegetation. To give an indication - 100liter of water transpired by a tree equals a cooling power of 70kWh, using energy received from the sun. Larger trees with deep roots can source water deep in the soil, thereby able to maintain transpiration, thus cooling even during drought and heatwaves.

However, in colder regions especially in winter forests and other vegetation could contribute to local warming due to limiting radiation of heat into clear skies. In Figure. 3 the effect different land uses have on how radiation energy from the sun could remain as heat in the local landscape, raising the local temperature is shown.

The cooling effect is influenced by scale and distribution of tree cover. Agroforestry can have a cooling effect in agricultural areas., and the preservation and establishment of green spaces in and around urban areas can lessen micro-climate temperature extremes. By applying this knowledge about the effect of the water- and energy cycles could help with cooling of the microclimate, as well as the precipitation-recycling process.

Mechanism of how forests regulate water

Fog and cloud water capture

High altitude forests have a special ability to intercept fog and cloud droplets. Condensation on plant surfaces, provide

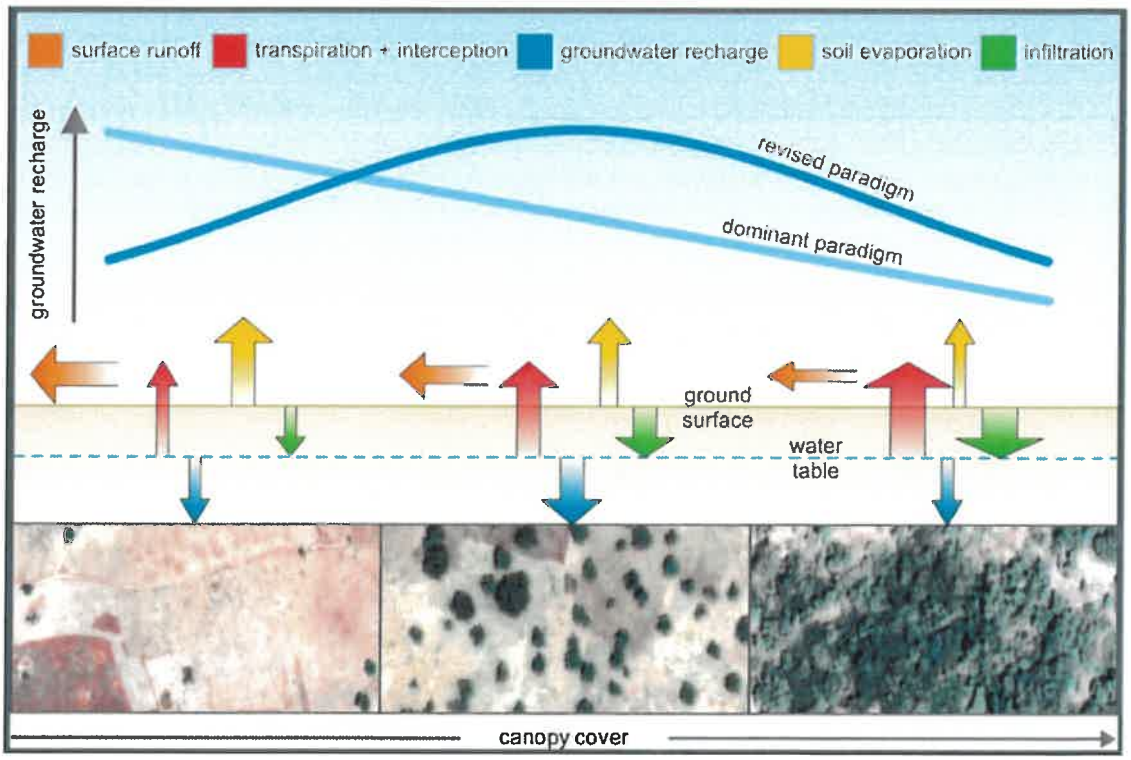

Fig 4. Infiltration and groundwater recharge related to canopy cover. Source: adapted from (Ilstedt et al., 2016). The size of the arrows is in proportion to the magnitude of each component of the water budget.

additional moisture for growth, evapotranspiration, infiltration, and runoff. It could then become available for precipitation at higher elevations. These forest areas seem to have higher infiltration rates and dry season flow than agricultural areas. Where these forests are removed, the atmospheric moisture might move to other areas, which could mean significant water loss locally and downstream.

Infiltration and groundwater recharge

Deforestation results in increased runoff, while sufficient vegetation cover and reforestation facilitates decrease in runoff. Deforestation which is inevitable when land use is changed to crop or animal husbandry, over time results in soil degradation. The carbon content of the soil decreases, and the soil structure is destroyed. The infiltration rate as well as the water holding capacity of such damaged soils are impacted negatively. The subsurface groundwater reserves are thus not replenished sufficiently, with the consequence that eventually dry season base flows cannot be maintained any longer. Previous perineal streams now only flow after rainfall events. Establishing trees in agricultural fields (agroforestry) can result in increased infiltration capacity due to increased soil organic matter from dropped leaves as well as the increased root network, macro- and micro soil life, and shading. Each tree can improve soil hydraulic properties extending up to 25 m beyond its canopy edge. Note, that different tree species each have unique water use characteristics. Therefore, if the yield of the catchment is important, appropriate tree species should be chosen.

Closing remarks

The land use in the upstream part of a river catchment has a direct effect on water availability in the downstream parts of the river. Similarly land use in the upwind areas of a continent, relative to the global prevailing wind patterns, have an influence on the atmospheric moisture content and potential precipitation in the downwind locations on the specific continent.

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