Trans-SEC

Innovating pro-poor Strategies to safeguard Food Security using Technology and Knowledge Transfer

Contract number: 031A249A

Work package number 4

June 2015

Deliverable 4.4.2

Water resources situation in CSS

General conditions of water resources in Kilosa and Chamwino district and expected implications for agricultural and food security strategies

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Introduction

The present report was compiled in frames of the Trans-SEC project, which aims at improving the food situation for the most vulnerable rural poor population in Tanzania through the identification and dissemination of successful upgrading strategies (UPS) for small-scale agricultural production. Research for the Trans-SEC project is implemented by a large consortium of experts from a range of political, social, economic and natural resources backgrounds to cover the complex realities of agricultural production in rural Tanzania. The task of the *hydrologic work group* is to provide an assessment of the state of water resources and expected future developments, and to evaluate the implications for agricultural food security strategies. It also investigates how large-scale implementation of UPS would affect water resources in the project region.

In a first step, a comprehensive literature review was conducted to gather an understanding of the processes affecting water resources on drainage basin and regional scale in Eastern and Southern Africa. It also provided the frames for placing observed changes and pressures within a larger regional and temporal context, which is especially important for the assessment of future developments and also recommendations of action.

As it became apparent, Tanzania lies within a zone of strong hydrologic changes and reportedly high pressure from driving forces such as population growth, agricultural sector development, and climate change. In many cases, water demand already exceeds water availability, thus limiting food production and agricultural development (Besada & Werner, 2015; Gunasekara, Kazama, Yamazaki, & Oki, 2014). The Wami drainage basin, which is the site of the project field trials in Tanzania, is no exception to this case. In a second step, therefore, information on the concrete state of water resources in the sub-basins of the Trans-SEC case study sites was compiled. The findings described in the following sections are drawn from a number of relevant hydrologic sources, most importantly the 2015 "Atlas and Reports on the Wami/Ruvu River Basin" by Global Water for Sustainability Program (GLOWS-FIU), the 2013 "Study on Water Resources Management and Development in Wami/Ruvu Basin" by the Japanese International Cooperation Agency (JICA), and the 2010 "Wami Basin Situation Analysis" by the International Union for Conservation of Nature (IUCN)). The collated information on relevant hydrologic aspects provides important insights on the background of natural resources against which Trans-SEC is operating, and indicates framework conditions for the intended UPS.

Overview of study area (Wami river basin)

In respect to water resources, the common spatial boundaries are usually drainage basins. A drainage basin is a hydrologic unit which is defined as an area where precipitation runs off from the land towards one common point such as a river, lake or aquifer. The boundaries of a drainage basin are often marked by landscape features such as ridges or mountain flanks, which cause a distinctive divide of the direction the runoff is channeled to. Usually, drainage basins are named after the longest-running river or largest lake within a basin, and can be sub-divided into smaller sub-basins along the tributaries (USGS, 2014; WMO, 2012).

Drainage basin boundaries are geomorphologically defined and do therefore not exactly coincide with administrative boundaries. Figure 1 displays the different spatial boundaries related to in the present report. The four Trans-SEC case study sites (CSS) and the respective wards are located in the Wami catchment, while the respective districts only partially coincide with the basin. The CSS villages in Chamwino district (Ilolo & Idifu) are attributed to Kinyasungwe sub-basin, while those in Kilosa district (Ilakala & Changarawe) are attributed to Mkondoa sub-basin.

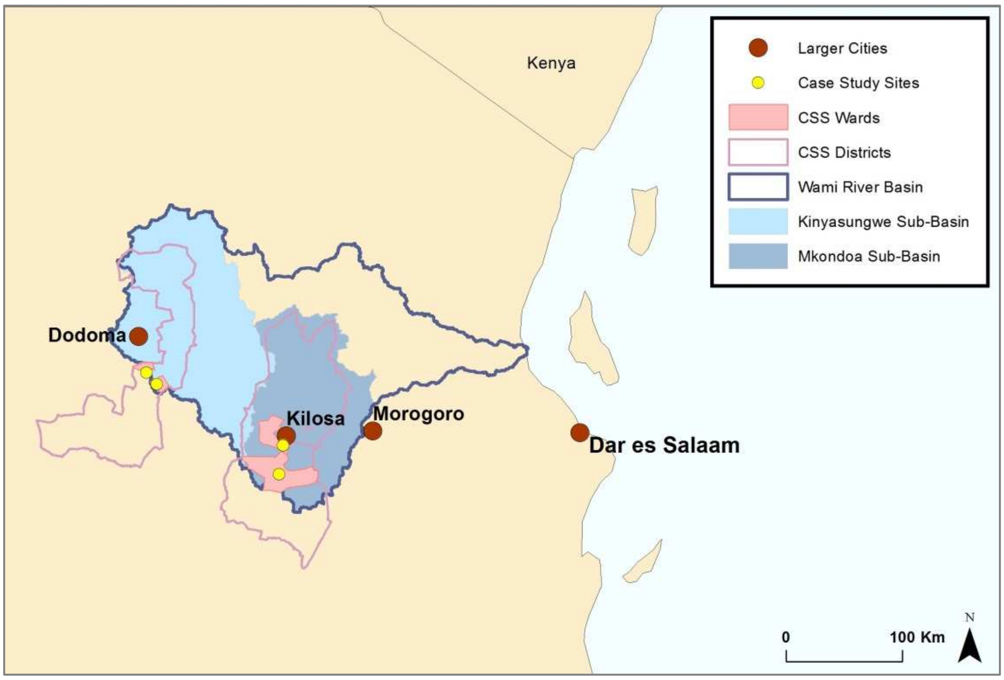


Fig. 1: Location of Trans-SEC study sites and associated districts and river basins in Tanzania

The Wami basin is 43,742km² large and covers the extent of the 637km long Wami river from its source in the Kaguru mountains in the west to its estuary in the Indian Ocean. It encompasses two national parks (Mikumi and Saadani), parts of the Eastern Arc Mountains (Ukagurus and Ngurus), and several protected forest sites; however, none of these are in the direct reach of the CSS. The elevation of the basin decreases from west to east, with Chamwino district located at around 1,000-1,300masl, while Kilosa district is around 600-900 masl. The differences in elevation as well as the distance to the sea are the main factors driving the climatic conditions of the basin, with semi-arid conditions in the western and increasingly humid conditions in the eastern part (see Figure 2). The inland receives one rainfall season around December, whereas the rest of the basin has two rainfall seasons with the major one between March-May ("Masika"), and the minor one between October-December ("Vuli"). Very little rainfall is recorded in the dry season of June to September.

The maximum temperatures are recorded in November – February and the minimum temperatures are recorded in June – August. Average annual temperatures are comparable at around 22-25°C in both regions; however, the temperature range is higher in Chamwino district. Potential evapotranspiration is also similar in both districts at around 1600mm/year (GLOWS-FIU, 2014c; JICA, 2013b, 2013c).

The flow of the Wami river and its tributaries is linked to the described rainfall patterns. As the basin lies in the meteorological transition zone between the bimodal and unimodal rainfall regimes, river flow regimes vary slightly depending on the amount of seasonal rainfall. Most large streams have a defined peak during the long rains and a second smaller peak during the short rains, with high flows during periods of heavy rainfall. The lowest flow is typically experienced in October, but low or no flow periods extend longer for seasonal rivers. The rivers support a number of small- and larger scale irrigation schemes, but the majority of agriculture is rain-fed. There are no larger industrial complexes or cities in the CSS vicinity, and the population density is about 100 persons/km² in both Chamwino and Kilosa district (GLOWS-FIU, 2014a, 2014c; IUCN, 2010; WRBWO, 2008).

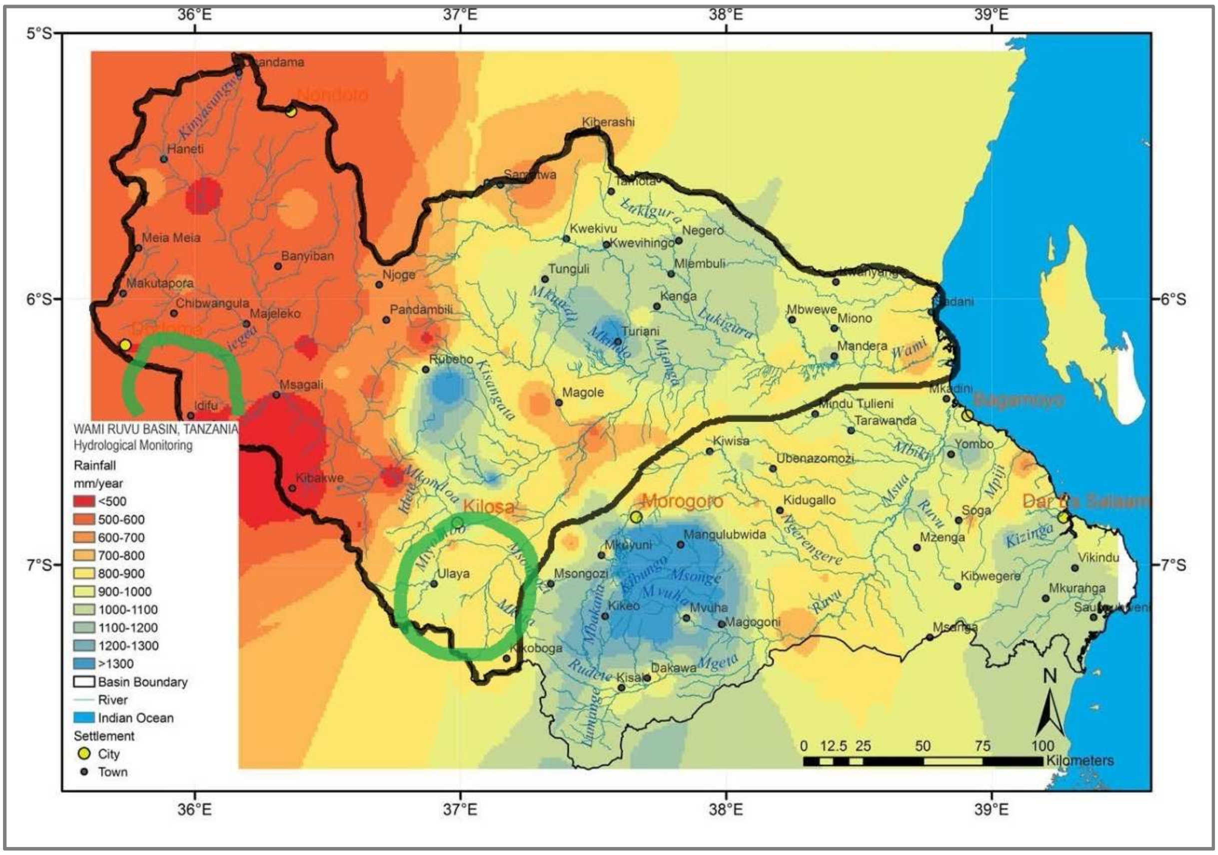


Fig. 2: Isohyets showing annual rainfall averaged over 1950-2010

Map from Water Atlas of Wami/Ruvu Basin, p.67 (GLOWS-FIU, 2014c) with own edits

(Wami river basin is part of the Wami/Ruvu basin; above Wami basin is outlined in bold black, CSS wards in green)

Current status of water resources in case study sites

Chamwino district (Kinyasungwe sub-basin)

Chamwino district is a predominantly rural area, with the vast majority of households engaging in smallholder crop production and possibly livestock keeping. Off-farm income sources are limited, and the literacy rate is comparably low (63%).

Chamwino district encompasses two CSS, namely Idifu (Idifu ward) and Ilolo (Muungano ward). Both of these wards together cover approximately 230km², which is only a small portion of the total 16,483km² of the Kinyasungwe sub-basin.

Both CSS lie along an unnamed ephemeral river[a] which is a southern-west tributary of the Kinyasungwe river (Fig. 3) (GLOWS-FIU, 2014c). Ilolo village is partly within Rufiji river basin, but the largest portion drains to the Kinyasungwe river; it can therefore be attributed to the Wami basin (JICA, 2013b, 2013d; Masikini, 2013).

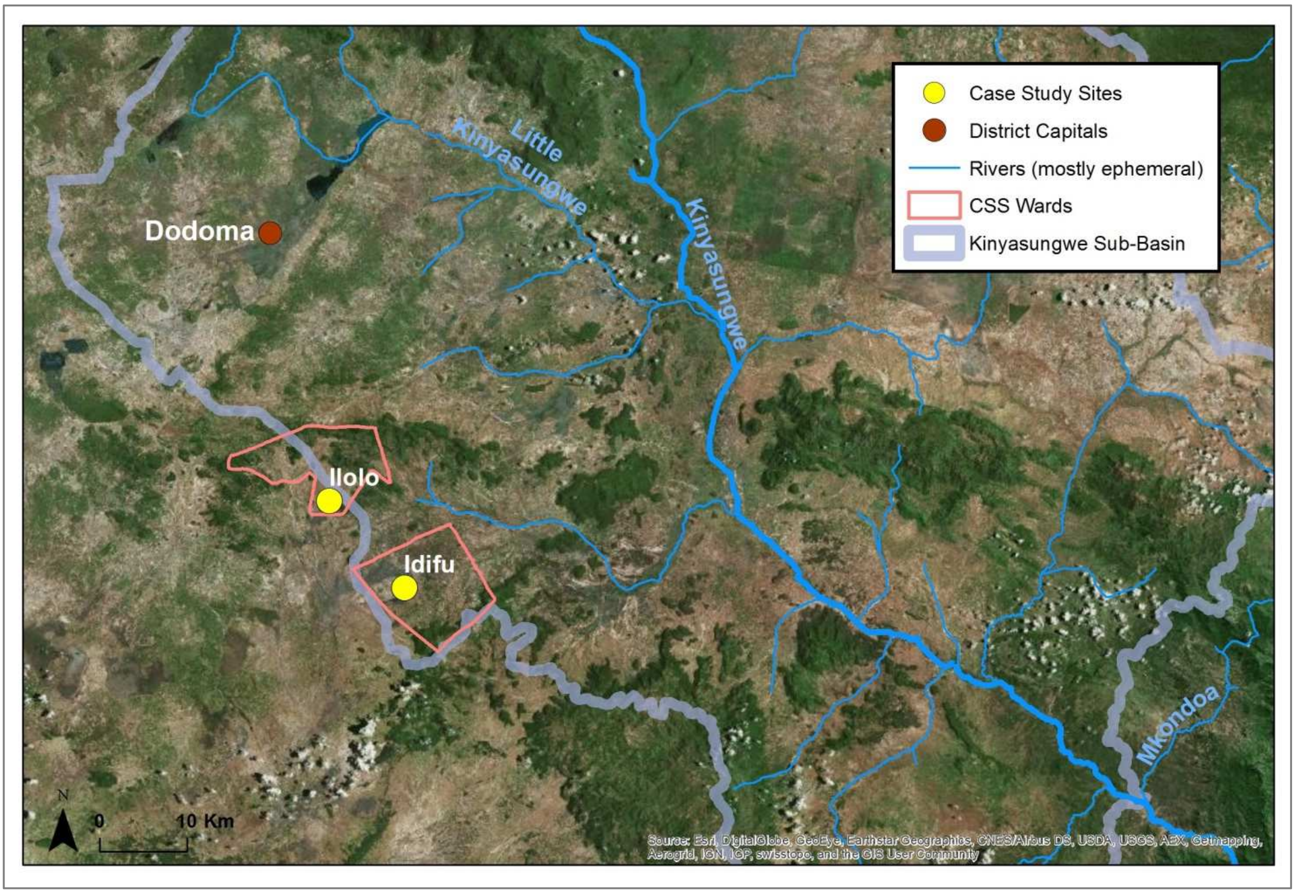


Fig. 3: Ilolo and Idifu CSS and wards in Kinyasungwe sub-basin
(Own waypoints, Shapefiles from JICA (2013c), Background image from ArcGIS World Imagery Basemap 2015)

[a] An ephemeral river only exists for a short period following heavy precipitation. It is not the same as a seasonal river, which exist for longer periods, but not all year round.

Rainfall and climate

Average rainfall in the Chamwino CSS is around 500-600mm/year. Observations from long-term time series (1901-2011) show inter-decadal cycles of high and low rainfall, which are related to global climate cycles such as the El Niño Southern Oscillation (ENSO). Rainfall is also strongly linked to local topography and land use (GLOWS-FIU, 2014a, 2014c).

Annual mean air temperature in the Wami/Ruvu basin shows a clear increasing trend since the mid-1900s. The increase ranges from 0.014 to 0.026°C/year (JICA, 2013c).

River flow

The Kinyasungwe river is the major river draining the upper catchments of the sub-basin. Its headwaters are in the arid areas of Dodoma and it flows south-east to discharge into the Mkondoa river. At Konga gauge, it has an annual specific discharge of 18,958 m^3/year/km^2 in a normal year, and 2,292 m^3/year/km^2 in a dry year (JICA, 2013b). In such dry years, prolonged cessation of river flows is common. Flow is highly variable inter-annually without any clear trend. Almost all rivers in the Kinyasungwe basin are predominantly ephemeral or seasonal, and typically flow only between November and May. There is also an ephemeral floodplain in the vicinity of Idifu village (GLOWS-FIU, 2014a, 2014b, 2014c).

Groundwater

Groundwater is still relatively abundant in Tanzania, and the granite and migmatite formations found in Dodoma and Chamwino district are favorable in terms of yield and accessibility. Average depth to the water table is about 26-50m, and the static water level in boreholes is around 0-10m. Although the largest number and highest yielding wells are further to the north of the district (i.e. Makutupora, with yields of around 89 m^3/h), both CSS wards also rely strongly on groundwater for domestic use and livestock supply. In addition, shallow wells are dug in river beds for small-scale irrigation (GLOWS-FIU, 2014c; IUCN, 2010; JICA, 2013b).

Water supply infrastructure

The most common source of drinking water in Chamwino district is piped water from underground sources (GLOWS-FIU, 2014a; NBS & OCGS, 2012b). Official statistics indicate that 50-75% of households have access to such improved water sources. However, recent surveys have shown that the status of water supply infrastructure in rural areas is poor. In Idifu and Muungano ward, 1 water point[b] serves an average of 1000 people, and Chamwino district has one of the highest proportions of agricultural households obtaining water from a distance above 20 km (especially during dry season) (IUCN, 2010; NBS & OCGS, 2012b; Tanzanian Ministry of Water, 2013a).

Water sources for livestock are mainly from groundwater, although surface water features have been historically utilized when available. A number of new boreholes and smaller dams ("Charco dams") are found for that purpose in Chamwino district, but no reservoirs with more than 750m^3 storage capacity (GLOWS-FIU, 2014a; IUCN, 2010; Tanzanian Ministry of Water, 2013a, 2013b). Water for irrigation is primarily drawn from rivers or shallow floodplain wells, mostly without further infrastructure (GLOWS-FIU, 2014a; NBS & OCGS, 2012b).

[b] The point at which water is intended to emerge from a public, improved water supply, such as a tap.

Sectoral water use

The primary use of water in Kinyasungwe sub-basin is irrigation (73%), followed by domestic (21%) and livestock (6%). All officially registered water use permits were issued for public water supply schemes. Water is chiefly drawn from surface sources (68%), but also from groundwater (32%). Currently, total water availability exceeds total water demand. However, this does not consider the temporal and spatial distribution of available water, i.e. that a large amount of surface water is available in a very short time only, and that access to groundwater is limited regionally and structurally. It is also not entirely clear how the current abstractions affect basin water resources due to lack of comprehensive monitoring (GLOWS-FIU, 2014a, 2014c).

Main factors affecting water resources

- *Population development*

  A total of approximately 20,000 people were living in both CSS wards together in 2012. The regional population growth rate between 2002 and 2012 was 2.1%, which is 0.5% higher than the previous decade, and implies a marked population increase in the past ten years[c]. The present average household size is 4.3-4.6, and population density is around 50 persons/km² (NBS, 2006; NBS & OCGS, 2013).

- *Land use and land cover change (LULCC)*

  Chamwino district is mostly covered by bushland and grassland, with some sparse woodlands in the southern parts. 87% of potentially arable land is under cultivation. Crop production is primarily rainfed and there is only one cropping/harvesting season (only about 1% of annual harvest is grown during dry season, with irrigation from shallow river wells). The main crops are cereals, oil seeds and pulses. Agriculturally used land has increased by 14% between 2002-2012 (GLOWS-FIU, 2014c; NBS & OCGS, 2012b).

  A moderate but ongoing reduction of forest cover in Chamwino district is witnessed from 2000 to 2012. The majority of local households (96%) use firewood for cooking, and charcoal production for urban markets is a significant source of off-farm income (GLOWS-FIU, 2014c; NBS & OCGS, 2012b).

- *Irrigation*

  Chamwino district has the lowest irrigation ratio in Dodoma region. Low-scale irrigation on 273ha of vegetables and fruits is reported in the vicinity of the floodplains (0.19% of total planted area), but is still very little compared to e.g. Kilosa or even Dodoma district. No official irrigation permits were reported for Chamwino district (NBS & OCGS, 2012b).

- *Agrochemicals*

  The proportion of planted area using fertilizer in Chamwino district is low (11% of planted land). Interestingly, the total area where agrochemicals were applied has more than halved between 2003 and 2007. This development could be due to growing costs of the chemicals, adoption of integrated pest management approaches, or an increased use of varieties that are resistant to most pests (NBS & OCGS, 2012b).

[c] Tanzanian average growth rate = 2.7%, Ø household size = 4.8, Ø population density = 51 per km² (NBS & OCGS, 2013)

- *Soil water management practices*
  Water harvesting and/or soil erosion control measures are implemented by 6% of households[d] in Chamwino district. The following structures are most prevalent: unspecified (60%), terraces (30%), tree belts (13%), erosion control bunds (12%), and water harvesting bunds (5%) (NBS & OCGS, 2012b).

- *Livestock*
  Chamwino district has the third highest number of cattle in the region, with moderate number of sheep, pig and chicken. Most farmers keep livestock in addition to crop farming, and use of oxen for ploughing is widespread. Between 1984 and 1994, the numbers of cattle in Dodoma region have increased from 24 to 38 heads/km². Conflicts between farmers & pastoralist were reported by around 2-3% of households, but do not seem to be of major concern (IUCN, 2010; NBS & OCGS, 2012b).

Water quality

Surface water in Dodoma region has a generally very high electrical conductivity (2,780 µS) and pH (10-11.7), and high levels of sulphate (SO4). This is probably due to the prevailing geology and salty groundwater. Concentrations reduce with increased dilution further downstream. Concentrations of all other parameters, including heavy metals, were within the allowed limits under Tanzanian standards. The only exception with above standard values was ammoniacal nitrogen (NH3-N) (GLOWS-FIU, 2014b; IUCN, 2010).

Groundwater/tap water is generally of better quality, but often saline. Water from shallow wells was reported to often be very salty, and at several sites (one in Chamwino district), colibacteria were found in the samples. Such water can pose dangers for human consumption, and is of limited use for livestock or irrigation (IUCN, 2010; JICA, 2013c).

Kilosa district (Mkondoa sub-basin)

Kilosa district is a predominantly rural area, with the vast majority of households engaging in smallholder crop production. Off-farm income sources are available but structurally limited. Kilosa district has a literacy rate of 73%[e].

Kilosa district encompasses two CSS, namely Changarawe (Masanze ward) and Ilakala (Ulaya ward). Both of these wards together cover approximately 1650km², which is almost an eight of the total 12,787km² of the Mkondoa sub-basin. Changarawe partially lies within the floodplains of the Miyombo river, which is a tributary of the Mkata river, eventually flowing into Wami river. Ilakala is further off the river course, between Miyombo and Mkata rivers (Fig. 4) (GLOWS-FIU, 2014c).

[d] Tanzanian average = 4% (Tanzanian Ministry of Water, 2013a)
[e] Differences between genders apply; female literacy rate may be up to 6% below male literacy rate in Kilosa district. Interestingly, no such gender gap was reported for Chamwino district (NBS & OCGS, 2012a, 2012b).

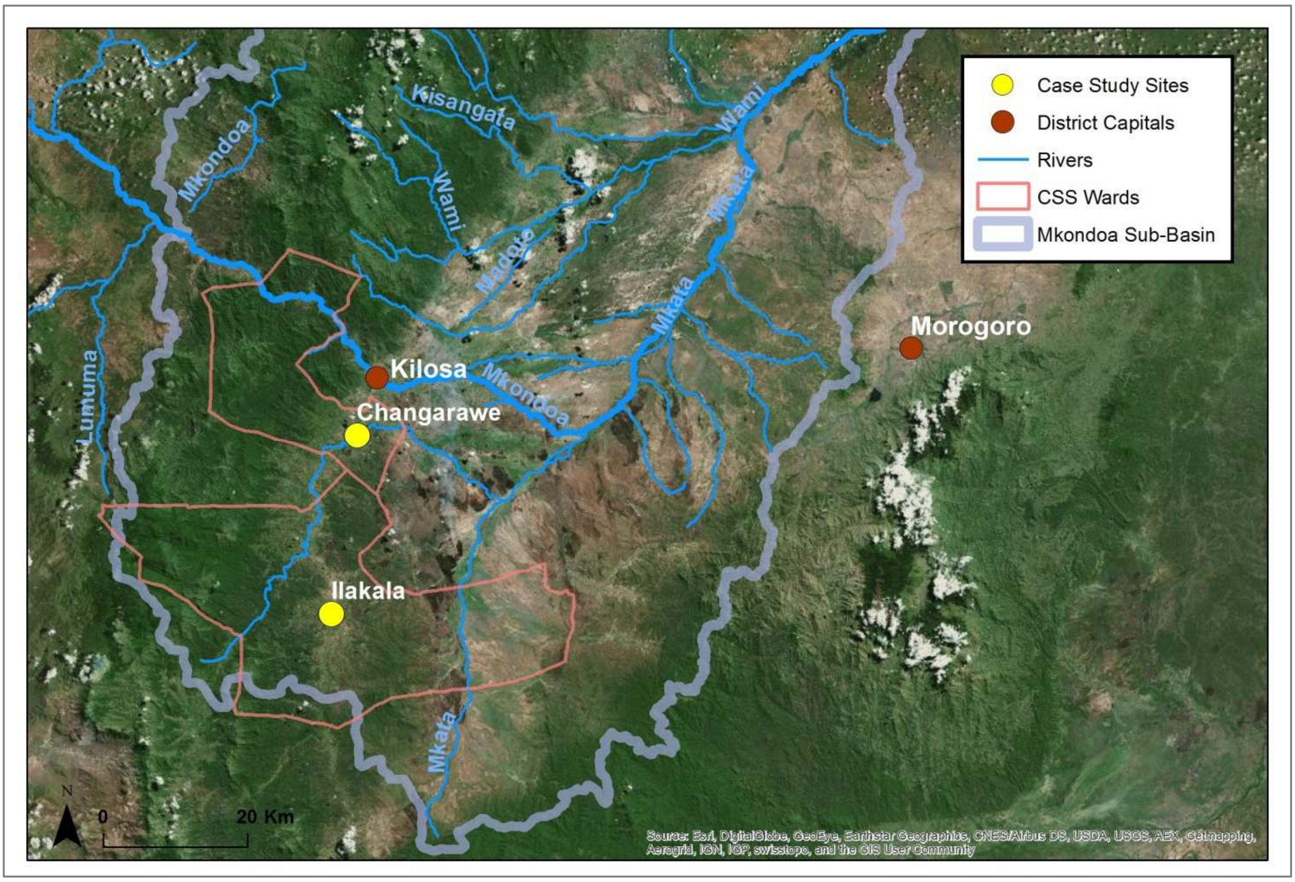


Fig. 4: Changarawe and Ilakala CSS and wards in Mkondoa sub-basin
(Own waypoints, Shapefiles from JICA (2013c), Background image from ArcGIS World Imagery Basemap 2015)

Rainfall and climate

Average rainfall in the Kilosa CSS is around 900-1000mm/year. Observations from long-term time series (1901-2011) show inter-decadal cycles of high and low rainfall, which are related to global climate cycles such as the El Niño Southern Oscillation (ENSO). Rainfall is also strongly linked to local topography and land use (GLOWS-FIU, 2014a, 2014c).
Annual mean air temperature in the Wami/Ruvu basin shows a clear increasing trend since the mid-1900s. The increase ranges from 0.014 to 0.026°C/year (JICA, 2013c).

River flow

The Mkondoa river is the major river draining the middle catchments of Wami basin. It flows south-east and is joined by several major tributaries, before discharging into the Mkata River, which still further downstream merges with other tributaries to form the Wami. At Kilosa gauge, the river has an annual specific discharge of 60,848 m^3/year/km^2 in a normal year, and 34,240 m^3/year/km^2 in a dry year. Flow is highly variable inter-annually without any clear trend, however, disturbance of forest cover and wetlands seems to lead to reduced infiltration/storage and increased instantaneous runoff. The Mkondoa sub-basin contributes the highest volume of flows in the sub-basin, and rivers in this hydrological zone are mostly perennial. Unfortunately, no flow records are available for the tributaries like the Miyombo in the CSS area. A sometimes flooded swamp is (GLOWS-FIU, 2014a, 2014b, 2014c; WRBWO, 2008).

Groundwater

The mainly metamorphic rocks found in the Kilosa CSS do not provide favorable conditions for groundwater extraction. Average depth to the water table is about 26-75m, and the static water level in boreholes is unknown. For these reasons, groundwater is not widely used in Kilosa district, and seems to be an option only for remote villages. Test drills during the JICA study[f] showed that yields with more than 20 m^3/h could be obtained in the western part of Kilosa district, but in the eastern and southern part (where the CSS are located) the average was closer to 2.2m^3/h. In addition, water quality tests revealed that a number of groundwater samples exceeded Tanzanian standards for total coliform, hardness, calcium, magnesium, and electric conductivity, giving cause for health concerns (GLOWS-FIU, 2014c; IUCN, 2010; JICA, 2013b).

Water supply infrastructure

The most common source of drinking water in Kilosa district is from underground sources, i.e. wells or taps (GLOWS-FIU, 2014a; NBS & OCGS, 2012b). Official statistics indicate that 50-75% of households have access to such improved water sources. However, recent surveys have shown that the status of water supply infrastructure in rural areas is poor. In Masanze and Ulaya ward, 1-2 two water points serve an average of 1000 people. This leads to large numbers of households relying on open traditional sources, such as handdug riverbed wells or seasonal rivers, as was also reported from the CSS (IUCN, 2010; NBS & OCGS, 2012b; Tanzanian Ministry of Water, 2013a).
Water for irrigation is primarily drawn from rivers and canals, lakes, or shallow floodplain wells, mostly without further infrastructure. A number of smaller dams are found for that purpose in Kilosa district, but no reservoirs with more than 750m^3 storage capacity (GLOWS-FIU, 2014a; IUCN, 2010; NBS & OCGS, 2012a). Livestock was not mentioned as a specific water user in Kilosa district statistics (GLOWS-FIU, 2014a; Tanzanian Ministry of Water, 2013b).

Sectoral water use

The primary use of water in Mkondoa sub-basin is irrigation (96%), followed by domestic use. Livestock does not feature as a separate water user. Officially registered water use permits were issued mainly for irrigation purposes, but also domestic use. The number of water use permits has increased fivefold since the 2000s, compare to the previous 50 years (JICA, 2013c). Water is almost exclusively drawn from surface sources (97%), and only to a very small amount from groundwater (3%). Currently, total water availability exceeds total water demand. However, this does not consider the temporal and spatial distribution of available water. Available surface water for example exceeds demand during the rainy season, but over-exploitation by upstream users in the dry season has led to reduced availability of flow to downstream users in recent dry years. Access to groundwater is further very limited regionally and structurally. It therefore needs to be seen how the current abstractions affect basin water resources due to lack of comprehensive monitoring (GLOWS-FIU, 2014a, 2014c).

[f] The Japan International Cooperation Agency implemented extensive in-field research on water resources in the Wami/Ruvu basin in frames of consulting services for the local water basin authorities.

Main factors affecting water resources

- *Population development*

  A total of approximately 25,200 people were living in both CSS wards together in 2012. The regional population growth rate between 2002 and 2012 was 2.4%, which is identical with the growth rate from the previous decade. It can be assumed that Kilosa district has experienced pressure from population increases for several decades now. The present average household size is 4.0, and population density is around 31 persons/km² (NBS, 2006; NBS & OCGS, 2013).

- *Land use and land cover change (LULCC)*

  Kilosa district is mostly covered by woodland, bushland and grassland, with some remaining light forests. 85-89% of potentially arable land is under cultivation. Crop production is primarily rainfed, but also to some extent irrigated, and Kilosa district has a significant proportion of crops planted in the dry respective short rainy season. The main crops are maize, paddy, sorghum and beans. No concrete figures were mentioned regarding the increase of agricultural land, but the shrinking size of natural vegetation cover coupled with the relatively small area planted with trees can be used as inferences of the extent of land clearing that has been done to give way to crop production (GLOWS-FIU, 2014c; NBS & OCGS, 2012a).

  Kilosa district has experienced a strong and ongoing reduction of forest cover from 1984 up to 2012. The majority of households (96%) use firewood for cooking, and charcoal production for urban markets provides additional off-farm income (GLOWS-FIU, 2014c; NBS & OCGS, 2012a).

  Lastly, it needs to be mentioned that the CSS in Kilosa district are located close (20-35km) to the Mikumi national park. The proximity to national park might imply certain restrictions as to land use/cover, or water resources management (GLOWS-FIU, 2014c).

- *Irrigation*

  In absolute terms, Kilosa has the largest irrigated planted area with around 4,500 ha (which is equivalent to 7% of the planted area) in the region. This encompasses smallholder irrigation, but also some commercial irrigation schemes of rice and sugar cane. Two permits for small-scale (less than 10ha) irrigation are noted in proximity to the CSS, and several others with up to 1,000ha further north towards Kilosa. The majority of households irrigate by using gravity schemes (80%, i.e. pipes or canals), followed by hand buckets (15%), motorized pumps (4%) and hand pumps (1%) (GLOWS-FIU, 2014c; IUCN, 2010; NBS & OCGS, 2012a).

- *Agrochemicals*

  The proportion of planted area using inorganic fertilizer in Kilosa district is moderate (17% of planted land). However, many farmers apply organic manure, which is more difficult to quantify. The planted areas applied with insecticides (30.6%), fungicides (33.4%), and herbicides (27.4%) are comparatively high, indicating potential pollution sources for water resources (NBS & OCGS, 2012a).

- *Soil water management practices*
  Water harvesting and/or soil erosion control measures are implemented by 4.9% of households in Kilosa district. The following structures are most prevalent: erosion control bunds (49%), terraces (23%), tree belts (15%), planting of vetiver grass, water harvesting bunds, drainage ditches (3% each) and gabion/sandbags (1%). About 1% of households further engaged in tree planting activities (NBS & OCGS, 2012a).

- *Livestock*
  Kilosa district has the highest number of agricultural households in the region, but only very small number of these keep livestock (2%) (NBS & OCGS, 2012a). In fact, cattle numbers in Morogoro region have decreased from 5 heads/km² in 1984 to 3 heads/km² in 1994/95. Conflicts between farmers & pastoralist were reported by 10--14% of households, indicating a potential major concern for the CSS (IUCN, 2010; NBS & OCGS, 2012a).

Water quality

No water quality sampling sites are within the CSS area, but some are a bit further downstream in Kilosa and findings might be insightful. Surface water from Mkondoa river in Kilosa has a moderate electrical conductivity (375 µS) and high pH (10). Water samples also showed concentrations of total suspended solids (TTS), and ammoniacal nitrogen (NH3-N) exceeding the allowed standards. Ammonia in its unionized form (NH3) is known to be toxic to fish. Usually it should be converted to nitrate via a nitrification process, but in water with high pH values, this process is limited (the pH at all sampling points in Mkondoa was greater than 8.5). Some of the rivers also contain a high content of phosphate (0.03 to 15 mg/l), indicating nutrient pollution. The most likely source of nitrogen and phosphorus in the Wami river basin is inflow of manure and fertilizer residues from agriculture. The trend of concentrations of phosphorus along the sampling points is related to the trend of TSS, indicating that most of the nutrients are contained in the suspended matter. Furthermore, bacteriological contamination i.e. with faecal coliform bacteria (ranging from 350 to 50,000 CFU/100 ml) is a major problem found in a set of river water samples from Mkondoa basin. Concentrations of all other parameters, including heavy metals, were within the allowed limits under Tanzanian standards (GLOWS-FIU, 2014b; IUCN, 2010).

Groundwater/tap water is generally of better quality, but results from the JICA test drills showed that coliform precedence and salinity are issues even with groundwater in Mkondoa basin. It seems that water quality is seriously deteriorating in areas with strong human impact (IUCN, 2010; JICA, 2013c).

Expected future developments in case study sites

The following sections provide a short outlook on the expected developments in the fields of climate, basin water resources, water demand, and the main factors driving these developments. The information will chiefly be on Wami basin scale, but where available, concrete statements for the sub-basins of the CSS are included.

Rainfall and climate

Rainfall amounts in the bimodal part of Wami basin are projected to increase slightly (by 2.1 - 2.9 %), while precipitation in the unimodal part is said to remain stable or decrease slightly over the next quarter century (GLOWS-FIU, 2014a; JICA, 2013c). Annual mean temperatures of currently 24°C are forecast to increase between 2.1 to 4°C, with a marked increase in very hot days (> 32°C). This would affect an increase of potential evapotranspiration (PET) by around 200-250mm/year by the 2090s. As a result, soil moisture is expected to decrease throughout the basin, with greatest deficits in the arid western region. An increasing frequency of extreme events – high rainfall events, floods and long periods of scarce or no rainfall – must be expected (GLOWS-FIU, 2014a; JICA, 2013c).

- Chamwino district (Kinyasungwe sub-basin)

  Projections estimate rainfall at around the current level for the rest of the 21st century. The main rainfall season may shift to January and February, when Chamwino actually receives higher rainfall than all other regions, but cease earlier i.e. in April. The lowest soil moisture deficit is predicted to be during April-June, and the highest deficit during July-September (GLOWS-FIU, 2014a, 2014c).

- Kilosa district (Mkondoa sub-basin)

  Projections estimate rainfall to increase by around 100-300mm/year for the rest of the 21st century. The main rainy season is expected to last longer i.e. til May, whereas the dry season (June – October) is expected to have very low rainfall (GLOWS-FIU, 2014a, 2014c).

River flow

Water balance calculations for the entire Wami/Ruvu basin have shown that under a trend scenario, water deficits will arise in the basin within the next two decades despite the stable rainfall levels. This will explicitly affect river flow, which is expected to decrease due to increased abstractions and unfavorable water recharge conditions in the basin (e.g. deforestation, flashier runoff). Due to the arid climate, rivers in Kinyasungwe sub-basin will be affected more severely, with longer and more pronounced water deficits, but Mkondoa rivers will also be concerned (JICA, 2013b).

Groundwater

Groundwater use is expected to increase in the next decades due to population growth (domestic supply), livestock, and irrigation demands. There are plans already for large irrigation projects based on groundwater, especially in the western semi-arid areas like Chamwino district. However, groundwater resources are indirectly vulnerable to climate change and land use change (resulting in changed recharge conditions) and not much is yet known about recharge rates and safe yields for the aquifers in Wami basin. Therefore, there is a significant risk of overexploitation of existing resources (GLOWS-FIU, 2014a, 2014c; JICA, 2013b).

- Chamwino district (Kinyasungwe sub-basin)

A high concentration of borewells can be found in the semi-arid Dodoma region, including Chamwino district. Groundwater is the primary source of water supply in such areas with low rainfalls and strong seasonality of flow. However, these conditions also imply low rates of groundwater recharge. While there is no data for wells in the CSS district, a long-term analysis of the Makutupora well field in Dodoma region revealed that recharge is extremely low (5 to 12 mm yr-1, equal to 1 - 2% of annual rainfall) and factually only occurs in rare years with extreme precipitation. Based on the annual specific discharge of Kinyasungwe river, very low recharge rates are to be expected throughout the sub-basin. This means that presently existing groundwater has built up over very, very long periods in possibly more humid past times, and that they are not being replenished under the current climatic conditions. Although little is known so far about the total volume of groundwater stored in Dodoma region, it is a finite resource. Already, groundwater tables in Makutupora have exhibited declining tables (from 1056 m in 2003 to around 1050m in 2008). In this region, there is therefore a concrete danger of falling water tables driven by extraction exceeding natural recharge (GLOWS-FIU, 2014a, 2014c; Rwebugisa, 2008).

Water supply infrastructure

Water supply infrastructure in rural areas of the Wami basin is currently mostly in a poor state, and given the rate of functionality and maintenance, it will probably take years before things improve[g]. Meanwhile, the situation impacts negatively on livelihood security (i.e. through low labour productivity caused by long distance/queues to water sources, and poor health of villagers). It is to be expected that people will exploit safer, nearer sources if they can afford them, which might lead to unregulated construction and increase of boreholes and hand dug water reservoirs/dams (IUCN, 2010).

In addition to these private efforts, commercial companies and state authorities will need to react to growing water demand by building new dams/reservoirs (see Appendix 1), and rehabilitating old ones. This can already be observed throughout the entire basin, and in the CSS regions. For the same reason it is expected that additional urban supply schemes like the Makutupora wellfield[h], or the Wami Water Supply Scheme, will be installed in Wami basin in the coming years (IUCN, 2010; JICA, 2013b).

[g] Governmental targets regarding rural water supply infrastructure include e.g. one water point per 250 people, and max. 30min round trip water fetching time. In 2013, however, only 1 out of 25 regions in Tanzania (Njombe) has so far reached this national target (Tanzanian Ministry of Water, 2013a).

[h] Makutupora wellfield is the water source for the entire Dodoma municipality. Wami Water Supply Scheme is a recently completed major urban supply scheme transferring water from the Wami river through 160km of pipelines to satisfy growing water demands in Chalinze township (Bagamoyo district). A second such scheme is already planned for the neighbouring ward (IUCN, 2010).

Sectoral water demand

Based on extrapolation of the current situation and assessment of the developments of factors affecting water resources, the future sectoral water demand in 2035 is estimated.

On Wami basin level, industrial and domestic demand are the two sectors that are forecast to grow the most, followed by irrigation. However, this encompasses a number of very large cities and industrial conglomerations that are far away from the CSS areas realities (JICA, 2013b). The share of surface water usage is expected to go up 2.6 times basinwide (from 716.3 to 1829 Million m^3), and utilized groundwater amounts will increase 1.9 times (from 193 to 373 Million m^3) (GLOWS-FIU, 2014a).

The total future water demand for Wami basin was estimated in the JICA water study by assuming three different scenarios: trend scenario (extrapolation of current situation), improved irrigation efficiency scenario, and industrial growth scenario. Total annual water resources (surface & groundwater) in the Wami basin would be sufficient to meet the demand in 2035 for all scenarios in both normal and dry rainfall years. However, only 15-20% of the total annual discharge can be stably utilized by humans, and therefore water demand both in the entire basin and in individual sub-basins is bound to exceed the usable amount of water resources by 2025 in dry years. Even with increased water storage capacities, the further development of groundwater potential, and increased efficiency of irrigation and industrial production, available water amount will be limited and even existing water permits will not be able to abstract the presently granted amount[i] (GLOWS-FIU, 2014a, 2014c; JICA, 2013b).

On a sub-basin level, annual water demand in Kinyasungwe sub-basin is expected to rise from 97 to 280 x 10^6 m^3, that is, almost triple. Even with an assumed increase of basin storage capacity through the rehabilitation of existing reservoirs (Dabalo, Hombolo, Buigili and Ikowa), constructing new reservoirs (Msagali, Ngipa) and transferring water from Farkwa Dam in the Internal Drainage basin, Kinyasungwe is already experiencing water deficits in the present. It is expected that total water demand will exceed available resources by 2025 (GLOWS-FIU, 2014a; JICA, 2013b).

Mkondoa sub-basin receives a lot of water from headwater catchments in the Ukaguru Mountains. It is among the basins with a high potential for irrigated agriculture and the government is investing in the area to improve and expand irrigation schemes. Projections also assume construction of additional reservoirs (Ilonga, Eami, Kisangata and Tami), increased efficiency of irrigation methods, and development of groundwater resources. Total water demand is expected to double from 247 to 502 x 10^6 m^3 (GLOWS-FIU, 2014a; IUCN, 2010).

- Chamwino district (Kinyasungwe sub-basin)

  The projected water demand for Chamwino district respective Dodoma region is subsumed in Table 1. It is discernible that irrigation and livestock play a dominant role in the region, whereas other sectors are negligible (i.e. mining, industries, hydropower, commercial/institutional water use). Especially striking is the increase of expected irrigation water demand until 2035. The viewed sources did not state whether the increase of irrigated agricultural acreage is expected due to government or private investments. In any case, such expansion can only be sustained by groundwater extractions, a resource that needs to be treated very considerately in the region. Increasing irrigated agricultural production in areas with very high evaporation rates such as Dodoma region is very likely not a resource efficient strategy. Furthermore, the given figures translate into irrigation values of more than 2000 l/m², which indicate an *extremelye low* efficiency of irrigation water. Given the preciousness of water resources in the region, strong efforts should be geared at improving efficiency rates.

The expected tripling of water demand in Kinyasungwe sub-basin is mirrored in the figures for Chamwino district respective Dodoma region, and is driven to a large extent by growing irrigation water demand.

Table 1. Projected water demand by sector for Chamwino district/Dodoma region

(own compilation based on data from (JICA, 2013b, 2013c)

Sector	Current use (2011)	Future demand (2035)	Rate	Spatial reference
Irrigation	4.6 Million m^3/year (223ha)	19.6 Million m^3/year (959ha)	4.3	Chamwino district
Domestic	2.3 Million m^3/year	3.2 Million m^3/year	1.4	Chamwino district
Fisheries/Aquaculture	0.001 Million m^3/year (3 ponds, 450m²)	0.002 Million m^3/year	1.5	Chamwino district
Livestock (Cattle, Sheep & Goats)	4.8 Million m^3/year (4,803,779 m^3/year)	9.1 Million m^3/year (9,104,868 m^3/year)	1.9	Dodoma region

- Kilosa district (Mkondoa sub-basin)

The projected water demand for Kilosa district respective Morogoro region is subsumed in Table 2. It is discernible that irrigation plays a much greater role than livestock in Kilosa district, and that more diverse economies exist (represented by tangible demand for commercial and institutional water demand). Other sectors like mining, industries, hydropower and fisheries do not play a role in the region.

The lion's share of increased future demand is again attributed to an extension of irrigated agricultural production In Kilosa district, mainly surface water will be the probable source for this water, and available water resources are greater than in Chamwino. However, the matter of irrigation efficiency is just as pressing here as there. The expected increase of cattle – which is contrary to the described declining trend in the past decade – may be explained by growing markets for dairy and improved meat processing in the region, or by more farmers keeping supplementary livestock (GLOWS-FIU, 2014a; IUCN, 2010).

The expected doubling of water demand in Mkondoa sub-basin is mirrored in the figures for Kilosa district respective Morogoro region, and is driven to a large extent by growing irrigation water demand.

Table 2. Projected water demand by sector for Kilosa district/Morogoro region
(own compilation based on data from (JICA, 2013b, 2013c)

Sector	Current use (2011)	Future demand (2035)	Rate	Spatial reference
Irrigation	19.2 Million m^3/year (9,200ha)	41.5 Million m^3/year (19,820ha)	2.2	Kilosa district
Domestic	6.4 Million m^3/year	10.1 Million m^3/year	1.6	Kilosa district
Commercial & Institutional	0.08 Million m^3/year	0.13 Million m^3/year	1.5	Kilosa district
Livestock (Cattle, Sheep & Goats)	2.8 Million m^3/year	5.4 Million m^3/year	1.9	Morogoro region

Main factors affecting water resources

- *Population development*

  The projected growth rate of the population in Chamwino and Kilosa district until 2035 is 1.4 and 1.6, respectively. This is a slightly reduced rate compared to the previous decades, but still translates into a far-reaching factor. Also, the total population of Tanzania is expected to double within the next 25 years, implying a massively growing demand for food, water, and industrial/commercial products that will have its impact on all regions (JICA, 2013c; NBS & OCGS, 2013).

- *Land use and land cover change (LULCC)*

  It is expected that current processes of deforestation, including encroachment of protected forests, will continue. A further strong expansion of agriculturally used land is unlikely, given that close to 90% of arable land are already under cultivation in both CSS districts. It is more likely that land *use* will change, i.e. with more intensified agriculture, different crops, or tree planting (GLOWS-FIU, 2014a; NBS & OCGS, 2012a, 2012b).

- *Irrigation, agrochemicals, livestock*

  All these factors are expected to increase; details were partially already provided in previous sections. It is expected that agriculture will be more industrialised, with higher agro-inputs and more forms of processing at local sites, especially if programmes like SAGCOT[j] come into effect (ERM, 2012; IUCN, 2010). However, both CSS districts are not currently in the hot-spot areas of these developments.

[j] SAGCOT stands for "Southern Agricultural Growth Corridor of Tanzania" and is a major development concept pertaining to the encouragement of private sector investments in agriculture incl. agricultural industry and infrastructure in Southern

- *Soil water management practices*
  With the rise of temperatures and limitations of water availability, more effort must be made in future to produce crops and use resources more efficiently. Rain water harvesting and soil water management practices are expected to become more widespread in the coming decades, because promotion will increase, but also revenue will be higher under increasing resource limitations (IUCN, 2010).

Water quality

Given the described processes, a further deterioration of water quality at least in the coming two decades is to be assumed. Many water quality concerns get magnified in low-flow conditions, which are expected from excessive water abstractions as well as low baseflows due to LULCC and possibly climate change. The major non-point pollution source in Wami basin is nutrient-enriched sediment washed into the waterways, and erosion is expected to increase over the next years, too, if no serious counter measures are adopted. In addition to sedimentation, point pollution both from lacking/poorly constructed sanitary facilities and from (agro)industrial complexes are expected to increase due to population growth, urbanization, and industrialization tendencies (GLOWS-FIU, 2014a; IUCN, 2010; Madulu, 2005).

Implications for agricultural food security strategies

The presented details on the current situation and even more importantly, the outlook on expected future developments, should give a first overview of implications arising for sustainable agriculture and food security efforts in the CSS. It becomes clear that a physical natural resource boundary – in that case for water – exists in at least one site, and that a range of pressures are affecting both sites with potentially negative consequences. In simple terms, food security is likely to be affected by a) the quantitative limitation of crop production potential (low yields), b) the qualitative limitation of crop production potential (restriction to few varieties), and c) the danger of complete crop failure due to extreme events. In terms of water resources, the affecting factors range from natural (rainfall extremes, floods, fires) to anthropogenic (over-exploitation, pollution).

Tanzania in the next decade. The Wami-Ruvu basin lies partly within the targeted growth corridor and will most likely be affected in some ways by the expected developments (ERM, 2012).

Natural factors can, to a certain extent, be prepared for and countered on a farmer's level. Anthropogenic factors, however, are only controllable by institutions and agreed laws and regulations. In regard to drainage basin water resources management, these two issues have been brought together with the two scales of action distinguishable for recommended measures to ensure sustainable water resources in stressed basins (Figure 5). Water is a key resource for agricultural production, and access to sufficient and clean water resources strongly impacts on food production and rural livelihoods.

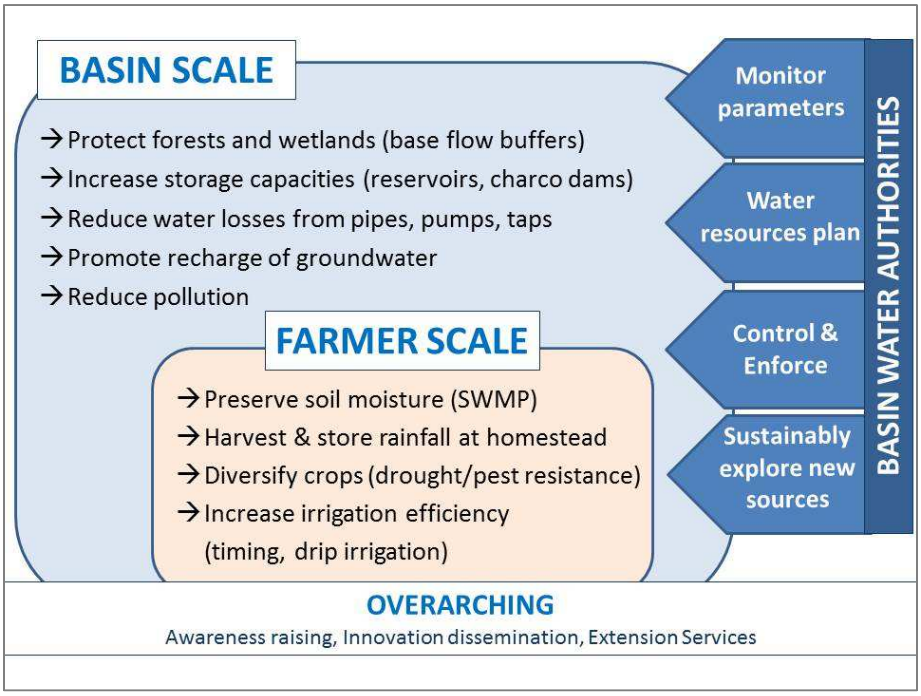


Fig.5. Simplified schema of potential measures for ensuring sustainable basin water resources (own compilation, based on recommended actions from reviewed literature)

The stated strategies[k] can help to minimize risks and avoid adverse impacts from the issues outlined in this report. However, they imply an integrated approach including stakeholder participation on all levels, and ideally a strong lead from the basin water authorities. The Trans-SEC project is rather geared towards the farmer scale of action. In this regard, a number of concrete recommendations can be given for each CSS region (Table 3 and 4).

Table 3. Overview of basin features and potential UPS measures for Chamwino CSS (Kinyasungwe)
(Own adaption of table from p. 62 of GLOWS-FIU (2014a)

Features & water sources	Climate: semi-arid region; Surface water: ephemeral rivers, strong seasonal water deficits; Groundwater: , low groundwater table, easily accessible and high-yielding, but very low recharge rates
Main water use sectors and future demand	Irrigation, Domestic, Livestock Total water demand is expected to <u>triple</u> by 2035
Main risks **(within scope of Trans-SEC / Farmer scale)**	- Temperature increase, pronounced soil water moisture decrease - Strong and potentially increased seasonality of flow - Increased likelihood of droughts

[k] Obviously, there are countless other; these only encompass hydrologic and soil-related measures.

Measures	- Collection of runoff and storage in hand-dug charco-dams (cattle) - Rooftop rainwater harvesting and storage in tanks (domestic) - Increased efficiency of irrigation, i.e. dusk time irrigation, drip irrigation, reduced losses → irrigation is only recommendable in such climate to counter dry spells in sensitive cropping periods - Soil water management practices (SWMP, see Appendix 2) to conserve soil moisture - Drought resistant resp. higher water-use-efficiency crops

Table 4. Overview of basin features and potential UPS measures for Kilosa CSS (Mkondoa sub-basin)
(Own adaption of table from p. 62 of GLOWS-FIU (2014a)

Features	Climate: humid; Surface water: perennial rivers, some seasonal water deficits and risk of over-abstraction in dry season; Groundwater: deep groundwater table, difficult to access and not very high-yielding
Main water use sectors and future demand	Irrigation, Domestic, Livestock, Commercial Total water demand is expected to double by 2035
Main risks **(within scope of Trans-SEC / Farmer scale)**	- Changes in rainfall seasonality - Temperature increase, soil water moisture decrease - Increased likelihood of droughts but also flash-floods
Measures	- Diversification of crops (range of water efficiency, pest-resistant) - Increased efficiency of irrigation, i.e. dusk time irrigation, drip irrigation, reduction of water losses - Soil water management practices (SWMP) to conserve moisture - Rooftop rainwater harvesting & tank storage (domestic, homegarden)

The above mentioned measures can be easily combined with other UPS strategies like improved grain storage, fertilizer application, weeding, etc. In regard to water resources on farmer level, the main focus should be on increased efficiency of water use and improved storage of soil moisture. The major constraints will probably be activities and investments competing with these strategies for time and money. Furthermore, if strategies are only considered at farmer level, there is a risk of creating unintended new problems for other stakeholders at the next level (i.e. down-stream users receiving less flow due to excessive runoff-harvesting). As long as the impacts of such strategies are not well understood, it is recommendable not to forget the basin scale perspective when dealing with water resources.

Supplementary notes

The present report provides a *basic overview* of the current and expected situation of water resources in the CSS regions at different levels. It is by no means exhaustive. As explained in the introduction, the collated information relates to different references systems (region, district, ward, hydrologic river basins), and is often not exactly attributable to the CSS. Care was given to always select the spatially closest reference, and the collated information should provide a sound overview of environmental factors and processes affecting water resources in the CSS, but any generalization from and transferability of findings between levels needs to be treated cautiously.

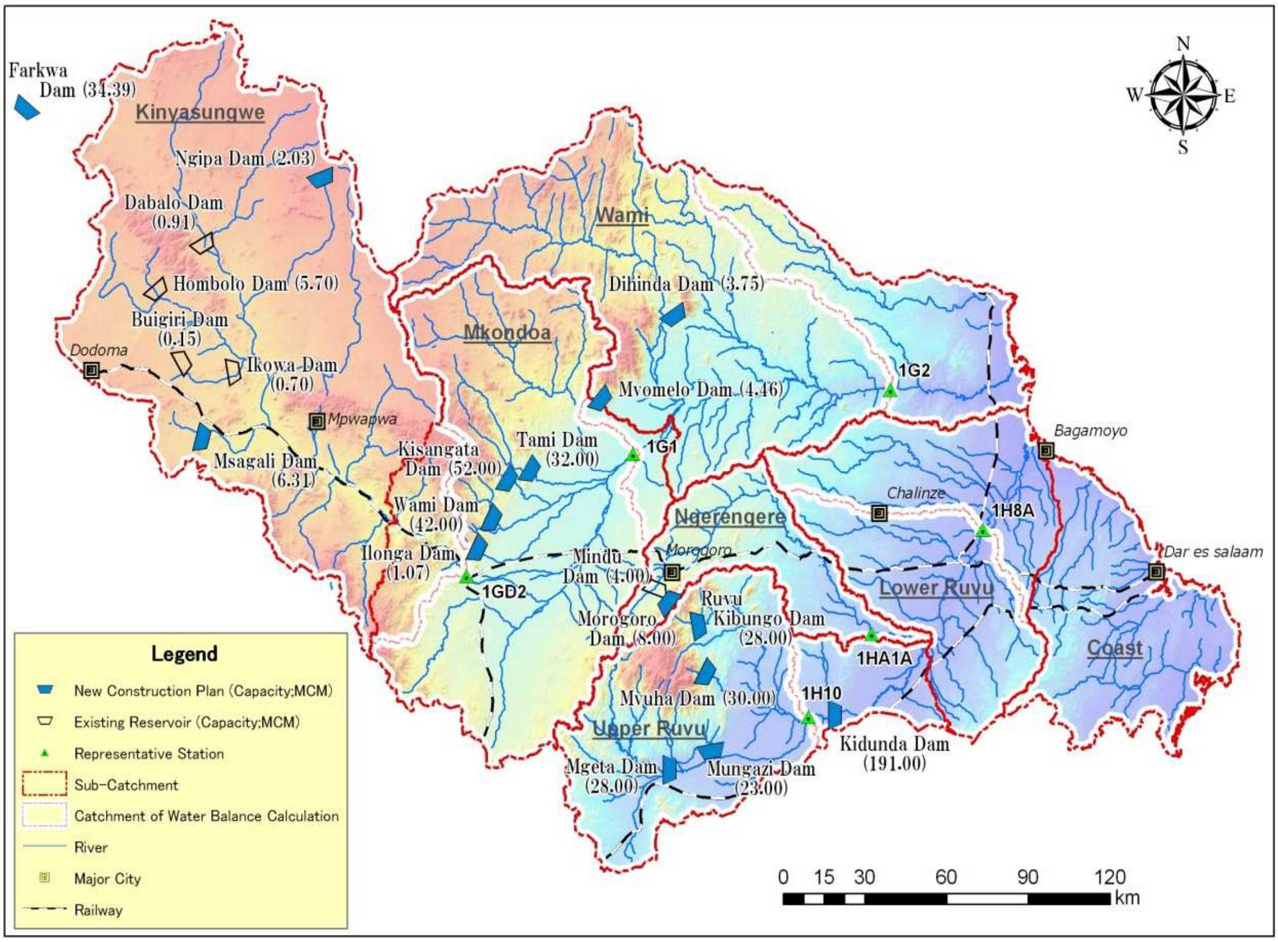
The data collated and presented is rendered as stated in the reviewed sources. While the information obtained was generally of high quality, sometimes deviating data was noticed between the sources. This was not further investigated but is most likely due to different basic assumptions especially in regard to future projections. In general, uncertainty regarding future developments is high (for instance, a 10% increase or decrease in projected streamflow is within the range of uncertainty in rainfall projections) (GLOWS-FIU, 2014a).

The most important limitation of the stated findings pertains to the low temporal and spatial resolution of the available data. The main statements in all sources focus on *total annual* water amounts in the assessment of future water demand versus water availability. While this is an important figure, it provides no information on the month-by-month distribution, although the latter ultimately affects people and agriculture more strongly. The yearly total can, for example, be well above the estimated demand, but what if all water is only available in three months? This is exactly the case at some of the investigated river gauges and shows that the described issues of water deficits are even more pronounced if regarded on a monthly base. While total water demand is projected to exceed total water availability in the Wami basin by 2035, *seasonal* water demand is likely already exceeding available resources in quite a few cases (see Appendix 3).

It is not possible to directly transfer these findings to the CSS, because the Wami basin is highly diverse in topography, geology, and micro-climates, and available data is limited to a few river gauges and sampling sites that are all not very close to the CSS. Therefore, more site-specific data would be beneficial to formulate findings at higher resolution. However, the available data should provide an idea of the prevalent general framework and tendencies.

Appendix 1: Existing and proposed reservoirs in Wami/Ruvu river basin

In the JICA 2013 water balance study of the Wami/Ruvu basin, options for improved future water supply were assessed. One important strategy includes the storage of water in the rainy season for later use in the dry season. The following figure provides an idea of the existing and proposed new reservoirs and dams in the Wami/Ruvu basin (Wami basin is in the left-upper part). The existing dams (hollow black trapezoids) are to be rehabilitated, including heightening of dykes and the crest of the spillways to increase storage capacity. The blue trapezoids are sites of proposed new dams and related reservoirs, to be constructed in the next two decades (JICA, 2013b).



Location of existing and proposed dams in the Wami/Ruvu basin (p.4-4 of Main Report (JICA, 2013b))

Appendix 2:
Soil Water Management Practices (SWMP)

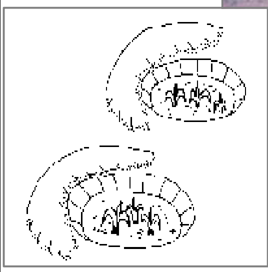
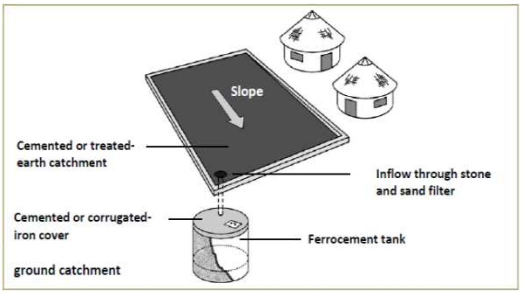
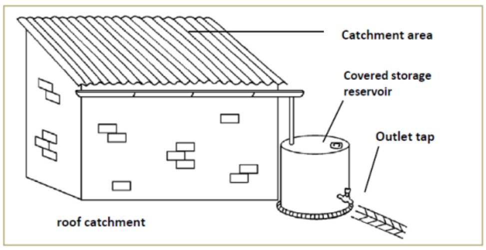
In light of the described prospects, agricultural strategies for the CSS must factor in *limitations of total and/or seasonal water availability.* This implies two important aspects to maintain and/or increase overall production and contribute to ensured food security: firstly, the efficiency of water use needs to be increased in all respects; secondly, water needs to be used more specifically to combat potential shortages during sensitive cropping periods.

One strategy to attain these results could be the implementation of soil water management practices (SWMP). SWMP can be broadly grouped according to the following categories: (I) practices aiming at maximizing infiltration, reducing surface runoff and evaporation, and improving soil moisture storage in the root zone, (II) micro-catchment (in-situ) rainwater harvesting methods, and (III) macro-catchment rainwater harvesting and storage techniques. These measures can be can implemented locally, without high investment coasts, by either individual farmers or small collective groups, and further supported by additional practices such as improved timing of seeding, or increased weeding (Biazin, Sterk, Temesgen, Abdulkedir, & Stroosnijder, 2012; FAO, 2008).

A lot of research has been conducted in regard to SWMP and its effect on yields and soil parameters on plot scale. The positive effects (e.g. soil water content in the root zone increasing by up to 30%, and yields doubling to even sextupling, if fertilizer is being applied at the same time) are encouraging and indicate and large potential for stabilized or even increased crop production (Biazin et al., 2012; FAO, 2008; Ngigi, Savenije, & Gichuki, 2008; Rajabu, Mahoo, & Sally, 2005; Rockström, Barron, & Fox, 2002).

In addition, SWMP has shown to be a potential tool to stabilize hydrologic parameter development at drainage basin scale. Studies from Ethiopia for example indicate that large-scale implementation of SWMP (in this case, gully stabilization, hill side terracing, planting of forage grass and trees along exposed hillsides, abandonment of post-harvest grazing, and cordoning off of degraded land) can lead to a reversing of negatively connoted hydrological changes. In the described region, mentions of positive effects comprise the cessation of flooding hazards, the rise of groundwater tables and subsequent re-emergence of shallow groundwater wells, and the restoration of riparian vegetation. Ten years after the interventions started, overall water availability in the catchment had increased significantly (Alemayehu et al., 2009; Kiersch, 2000; Nyssen et al., 2010; Rockström et al., 2002).

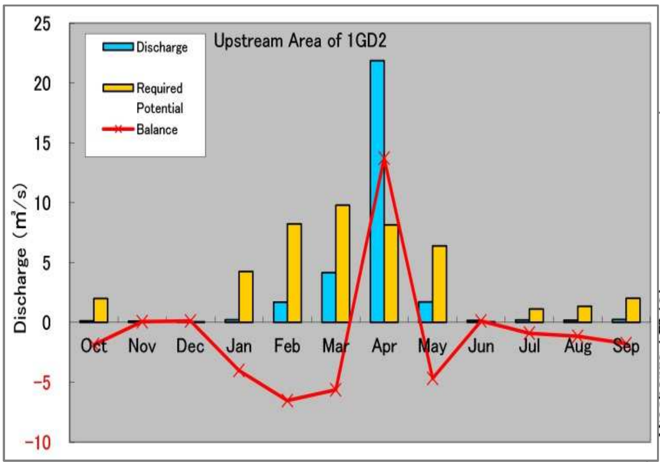
Table A1: Overview and examples of soil-water management practices by categories
(own rendering, adapted from Biazin et al. (2012), with data from Rockström et al. (2002) and FAO (2008))

Overview of soil-water management practices by category		
Category	Practices	Example
(I) Maximizing infiltration, reducing surface runoff and evaporation, improving soil water holding capacity, and maximizing root depth	Ridging, mulching, application of manure, various types of furrowing and hoeing, ripping, conservation tillage/agriculture, vegetation protection policies, contouring	 **Maize under conservation agriculture (no tillage), Malawi** ((FAO, 2013))
(II) Micro-catchment rainwater harvesting methods	Pitting (Zai pits), contouring (stone/soil bunds, vegetation barriers), terracing (Fanya Juu, hillside terraces), micro-basins (Negarims, halfmoons)	**'Zai' planting pits**   **' Halfmoons after rainfall** ((ICARDA, 2014))
(III) Macro-catchment rainwater harvesting and storage systems	*Rainwater collection* from rooftops, paved surfaces, natural slopes, rock outcrops --- *Water storage* in containers/tanks, underground tanks, traditional open ponds, micro-dams (Charco dam) and spate-irrigation systems --- *Water application* for irrigation, livestock or domestic use	  **Rainwater harvesting and storage systems** ((ClimateTechWiki, 1998))

Appendix 3:
Monthly water balance calculation for Kinyasungwe & Mkondoa rivers

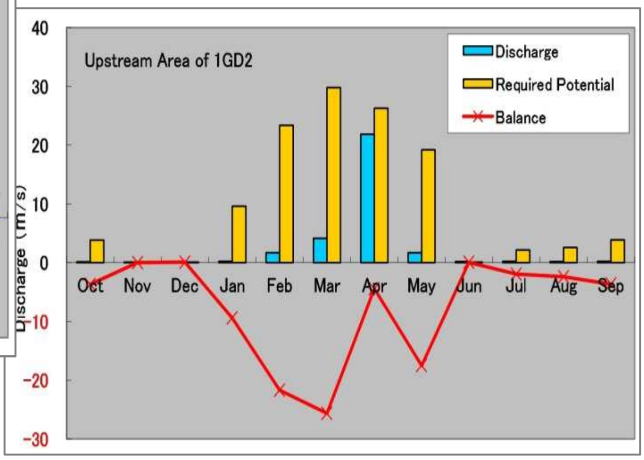
The following figures show the monthly water balance for two river gauge sites in the considered sub-basins. The balance is based on the monthly average discharge of a dry year (year of drought water discharge with 10 year return period), environmental flow and present water use (2011) respective future water demand (2035). They clearly show that seasonal water deficits (red line in below images) are already present, and will exacerbate in the future (all figures from p.5-7 of Interim Word Version of Main Report (JICA, 2013a) .

Kinyasungwe river (at outflow of Kinyasungwe sub-basin)

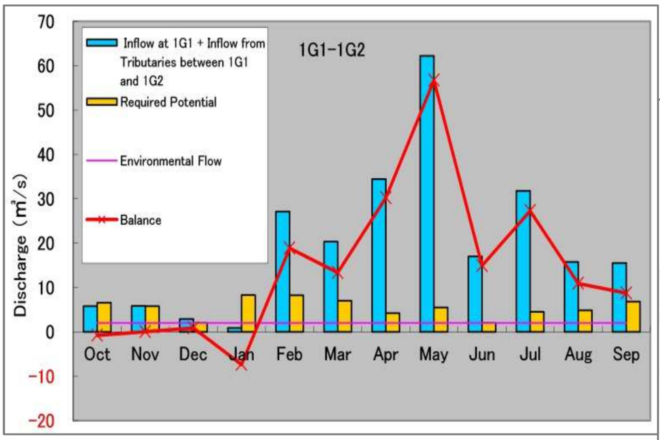


2011

2035

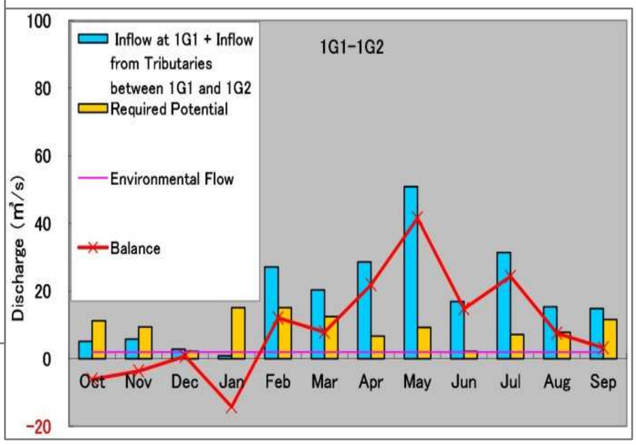


Wami river (at outflow of Mkondoa sub-basin)



2011

2035



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