COUNTRY STUDY CLIMATE CHANGE SURINAME

WATERRESOURCES
Prediction

Technical report no. 4a

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1 General

1.1 Introduction

Suriname relies basically on three types of water resources:

- Rainfall
- Surface water resources
- Groundwater resources.

1.2 Rainfall

In the northern part of the country the amount of rainfall is the smallest and increases up to the mid-center of the territory where the mountain ranges are located. For a more specific description of rainfall see the technical report part one. Due to the intense amount of yearly rainfall a dense network of rivers and creeks are to be found within the territory, which flows, directly or indirectly through other streams or rivers, into the Atlantic Ocean in the north. Rainfall is of a direct significance, mainly, in the agricultural areas, especially in the northern part where rice culture, horticulture, banana culture, and other water intensive cultures are practiced. In the rural areas where the facilities for water supply are lacking, rainwater is used for potable purposes.

1.3 Groundwater resources

Groundwater exists on large scale, which is a result, mainly, of Climatological and geological conditions of the area. Shallow and deep aquifers are found in the coastal strip, whereby, within the shallow reservoirs, freshwater lenses are found above the saline groundwater. Both, shallow and deep ground waters are renewable after abstraction with difference in extent and time of renewable. The Zanderij aquifer is probably the only extensive aquifer in the coastal plain that receives recharge directly by the infiltration of rainfall.

1.4 Surface water resources

The largest water resources are the open waters, rivers, swamps, and lagoons. A detail description of freshwater discharges is given in technical report part one (see also figure.2). For evaluation of the freshwater discharges the specific discharge has been determined. The specific discharge (which is the long-term average discharge divided by the area of the watershed) is relatively high. Table 1 taken from technical report part I, gives the annual discharge and the specific discharge of some rivers of Suriname.

Except for the rivers Nickerie and Commewijne specific discharge of the rivers is between 23-25 l/s/km^2. For Nickerie and Commewijne rivers the specific

discharge is about 18 l/s/km^2. The difference of about 5-7 l/s/km^2 illustrates the sensitivity of climate and the topography. The hydrological characteristics of the rivers in the coastal zone are sensitive to climate change. As mentioned in part one and in other technical reports, the coastal zone is mainly flat and its water balance is composed of mainly three components; rainfall, discharge and evaporation. Evaporation value consists of free open water evaporation and evapotranspiration by vegetation. A slight change in the climate will have large impacts on the water balance of the coastal zone, which might have serious (economical) consequences. For example, increase of temperature may increase the evaporation and or decrease the rainfall if the trends identified in the climatological elements as temperature and rainfall of the meteorological station Cultuurtuin may be taken as reference.

Table 1. Hydrological characteristics of the main rivers in Suriname

N	Main river	Catchment Area(km^2)	Discharge (m^3/s)	Specific discharge
1	Marowijne	68,700	1,780	25.9
2	Commewijne	6,600	120	18.2
3	Suriname	16,500	426	25.8
4	Saramacca	9,000	225	25.0
5	Coppename	21,700	500	23.0
6	Nickerie	10,100	178	17.6
7	Corantijn	67,600	1,570	23.2

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A water balance model called WATBAL is runned for river Nickerie to evaluate the runoff. The water balance model is an approach in modeling the impacts of climate change on flows of the concerned catchment, which is applied within the Nickerie basin. The basin is divided into two parts: the upstream area, which is the area beyond tidal influence, and the downstream area, which falls within the tidal influence. The model WATBAL is used for the upstream area. For the evaluation information such as precipitation, evaporation and runoff are used as input. By choosing combinations of parameters, runoff discharges are computed and compared with the observed ones. Doing so, the optimum combinations of parameters are selected (calibrated), and analyzing further should indicate the sensitivity of the water resources in relation to climate change. However both hydrographs, observed and computed, do not satisfy the match. The main reasons are poor data on rainfall and evaporation data, area of the catchment and large variations in rainfall within the catchment area.

2 Development

As has been stated in the technical report part 1, water resources are mainly used for two purposes, namely

1. Agriculture
2. Potable

The existing industries, which are relatively poor developed are using negligible amount of surface and ground water resources. Surface water resources are mainly used for agriculture purposes and for potable purpose groundwater resources. Depending on the location within the coastal zone the proportional use of these resources are varying. In the west of the country for example, surface water is used more intensively than groundwater. The most common problems are related to the quantity and quality of surface water resources, irrigation and drainage applications and facilities, flooding and saltwater intrusion. In Paramaribo and surroundings groundwater for potable purposes is the important issue. In the east, water related activities are less developed. In other words, development of water resources is related to other developments such as those of the socio-economical sector whether there is a sea level rise of one meter or not.

In both cases flooding analysis have been exercised for the entire coastal area for the present conditions, which means no sea level rise and for the future conditions, where a sea level rise of 1m is taken into account. For analyzing the flood risk zones the following are taken in regard:

- frequency analysis of the hydrological data of the rivers within the coastal areas
- natural and artificial obstacles within the area or in the watercourse
- vegetation and soil properties of the area
- existing dams, dykes and sea wall

- land-use development
- topographical features of the area
- expert judgement

Flooding of areas might take place from the:
- Atlantic Ocean towards the country. This is taking place in inter tidal area
- Rivers. Tidal intrusion from the sea into the rivers and the flow from upstream cause a back water effect, which may flood large areas.
- Rainfall. Rainfall in swamps may accumulate and due to sudden dam break large areas may be flooded.

Taking the above mentioned in consideration three flooding risk zones are defined:
1. zone which is flooded once a year, which is referred here as inter tidal area (Z1)
2. zone which is flooded once in ten year (Z10)
3. zone which is flooded once in 100 year (Z100)

The flooding risk zones for both conditions, present situation with no sea level rise and future situation with 1m sea level rise respectively are presented in figure 4 and 5.

Zone flooded once a year (Z1)

These are large areas of the coastal zone frequently temporary inundated by the tidal activity of the Atlantic Ocean under the present circumstances, the so-called inter tidal area. The inland border of this zone is the region where the ground level corresponds with the water level of the sea/river which is exceeded once a year. This inter tidal area is flat, consisting mainly of clay, which is a silt deposit from the ocean stream, locally exchanging with sand and shell ridges. Mangroves and other vegetation mainly occupy the areas in the zone. This zone also consists of salt, brackish and fresh water swamps. The whole area is poorly drained. In this area less or even no economical activities are practiced.

Zone flooded once in 10 year (Z10)

This zone covers large part of the cultivated land, areas upstream the rivers and lies beyond the inter-tidal area. Depending upon the infrastructure for protection against flooding this area may increase or decrease. When adequate infrastructure exists in a Z1 zone the flooding risk decreases and such area may be qualified as a Z10 zone. On the other hand a Z10 zone may degrade into a Z1 zone when the existing infrastructure is in bad condition.

Zone flooded once in 100 year (Z100)

Higher up located areas, as well as protected areas having a lower risk for flooding, are considered as areas flooded once in 100 years. These areas are mainly found beyond the zone flooded once in ten years.

Areas beyond the zone flooded once in 100 year are not taken in consideration. In the districts Marowijne, Para and Sipaliwini these areas are the largest, followed by de zone flooded once in 100 year, while in the west, the districts Nickerie, Coronie and Saramacca, the inter tidal area and area flooded once in 10 years dominate.

The last two zones (Z10 and Z100) cover mainly all economical activities in the coastal zone, which means that the major infrastructures, buildings, settlements, various types of land-use areas are found in these areas. At extreme highest high waters, which occur during the spring tide, large areas, falling even under zone Z10, may be flooded and degrade into a Z1 zone. This may be observed yearly as a result of poor maintenance of infrastructures and failure of other artificial structures, such as dams, dykes, sluices and culverts.

Here below, taking the above mentioned in consideration, water resources developments are discussed for each district individually.

3 District Nickerie

3.1 Surface water resources

District Nickerie is often taken and indicated as the area of northwest Suriname for integration purposes. However for integration purposes, the area of north-west Suriname is defined here as the area between the Coppename river in the east and Corantijn in the west, bordered in the north by the Atlantic Ocean and in the south by the southern border of the study area.
This area covers large surface water resources, as the Corantijn River, the Nanni swamp, the Nickerie River and the Coronie swamp.

The presence of fertile land and water resources in this region has made large agricultural development possible. Large amounts of fresh water have been used for agricultural purposes, especially for rice and banana culture. About 40,000 ha rice fields are irrigated yearly, which uses approximately 80 m^3/s. These amounts of fresh water are withdrawn mainly from the rivers Corantijn and Nickerie and the Nanni swamp.

The ongoing development of new rice areas depletes the amount of available fresh water of the mentioned resources. Yearly, about 100-200 ha new areas are being reclaimed, which means that additional water will be used. It is expected that at the end of 2025 a total area of about 50,000 ha will be in culture, which means a 25% increase of the existing rice area. The impact of this expansion will

be conveyed also in the water resources. Then a maximum of about 100 m^3/s will be used for rice cultivation. Expectation in expansion of the rice areas might be even higher, due to ongoing development in rice sector, the present potential land in the low lying coastal zone suitable for rice cultivation and the need for production. These potential areas for rice cultivation which are mainly the fresh water swamps are shown in figure 3.

3.2 Salt wedge intrusion and availability of fresh water

Salt wedge intrusion takes place due to the tidal motion of the Atlantic Ocean water and by withdrawing freshwater from the rivers for irrigation purposes. Large amounts of freshwater are being withdrawn from the rivers Corantijn and Nickerie. In technical report part one the salt limit in each river is highlighted, see also figure 2. As mentioned in this report, pumping station Wakay, located at 140 km from the mouth of the river, having a total pumping capacity of 30 m^3/s withdraws water from the Corantijn River for irrigation purposes. It is determined that saline water (chloride percentage of 300 mg/l or higher) reaches this location once in 5 years if the pumping station fully exploited is in operation. Full use of the pumping station is not made under the present conditions. However, the ongoing expansion of rice fields in the direct neighborhood of the Corantijn river will exhaust the existing possibility for irrigation within the next coming years and further expansion of rice fields will be halted because of freshwater shortage, especially, during the long dry season. Expansion of the capacity of pumps at Wakay could be a possible solution for partly liquidating freshwater shortages. New establishments of pumping stations seem to be excluded for economical reasons.

A second source of freshwater for the in neighborhood lying agricultural lands in district Nickerie is the Nanni swamp. Enlarging its water resources for irrigation purposes could take place by impeding the outflow of some creeks (e.g. the Kabouri creek) towards the Corantijn river. The Nanni swamp is less vulnerable to salination, however damming up the draining creeks (e.g. Kabouri creek) will result in a further salt intrusion in the Corantijn river.

A third freshwater source for the agriculture in this district is the Nickerie River and catchment. This includes the Maratakka river and the Maratakka swamp. Along the rivers expansion of rice fields is taking place. Shortage of freshwater for irrigation purposes for rice fields depending upon this source is therefore great and will increase if no additional measures are taken. The government recognizes this need and in this regard the establishment of a water reservoir has been planned in the upstream of the river, at Stondansie (fig 1). Excess water during the rainy season will be stored in the reservoir as irrigation supplement during the dry season or in period of freshwater shortage and the river flow will be regulated.

It should be mentioned that surface waters in district Nickerie, within and in the surroundings of rice fields, are polluted by the use of chemicals and fertilizers, such as herbicides and pesticides. This water is drained into the rivers. In the future the drainage water may be recycled, which may form an additional water resource for the district.

For a better management of the three mentioned water resources the government of Suriname has planned to integrate the utilization of these water resources and optimize the benefits.

3.3 Groundwater resources and potable water supply

For potable purposes currently about 14,000 m^3/day is withdrawn from groundwater in the district Nickerie. Potable water here is limited. Groundwater withdrawal takes place at a greater depth than that in Paramaribo. The amount of ground water is limited and sensitive to salt intrusion. Serious problems are ascertained as shortage of potable water, salinization of aquifers, etc. In many parts of the district rainwater is being used as potable water. Surface waters in the districts, especially in district Nickerie, within and in the surroundings of rice fields are polluted by the use of chemicals, such as herbicides and pesticides and is not suitable for potable purposes.

The use of potable water will increase parallel to the change (increase or decrease) of population (for more detail see technical report "Socio-economy, part 2"). Under the present situation withdrawal of ground water for potable purposes is in many cases limited by the intrusion of saltwater into the aquifers as a consequence of the withdrawals. When ground water is mined the risk for salt intrusion into the aquifers increases. If this development is continuing under the present circumstances, the intrusion of the salt limit will be located further into the coastal zone.

3.4 Flooding risks

District Nickerie might be flooded by one of the in chapter 2 mentioned factors or a combination of these factors. Failures in sea wall or dam breaks may have flooding by the sea or river as consequence. Flooding from the sea means a failure in sea wall or river dam break or penetration from other location of the shoreline. According to the stakeholders inquiry (see report "results of the Stakeholders meeting"), about 30% of the questioners in Nickerie finds that sea wall is weak and in case of seawall failure the surroundings will be flooded 11-50 cm and the damage will be enormous. The stakeholders call it a national catastrophe.

Flooding may also take place by the rivers, Nickerie and Corantijn as a result of backwater effect. In case of flooding from the Nickerie river damage will be greater than flooding from the Corantijn river. The difference is that along the

Nickerie river development of rice cultures are concentrated on both sides of the river, which is further upstream than along the Corantijn river. By reclaiming the flood plains of the river, cross section in particular will decrease and may cause flooding during high water levels.

Flooding of rice fields by the swamp water, in particular from the Nanni swamp occurs in time of excessive rainfall, whereby dams protecting the cultivated land against swamp water break. This has happened frequently in the past and will happen in the future, if no effective measures are taken.

3.5 Impacts of the flooding on water resources

Impacts of the tidal effects under present conditions (at 0 m sea level rise) on the economical activities are considerable. As mentioned above, water may spill over the sea wall or river dykes into the protected land at highest high sea water level, causing harm to economical activities and other branches of the socio-economical development. So, the highest high water level under the present conditions may be considered as critical, increase of which may result in greater harm and will affect larger areas then it takes place now. Population as well as capital values are at the present moment at risk. This risk will increase rapidly at SLR (sea level rise) of one meter. Except population and its socio-economical development, all coastal infrastructure become highly vulnerable due to increased wave height and wave force. The latest is well illustrated by data from WLA (Hydraulic Research Division), observed at Zeedijk (seawall) in regard to the rehabilitation of the seawall.

It has been stated that salt intrusion under the present condition reaches up to km 78, see technical report part one, which is at the location of state rice farm Wageningen. The penetration of salt wedge is highly dependent upon several factors among others the rainfall. If the amount of rainfall decreases salt intrusion may be maximum land inward. On the other hand if the of amount rainfall increases favourable conditions will occur for further development of rice fields in the area. If no remarkable increase takes place in rainfall, the conditions for further development will get worse. Enlarging the rice fields and reclaiming lands for new rice fields will exert additional pressure on the available fresh water resources and so saltwater intrusion in the river will accelerate due to the increased withdrawal of the water from the river.

For irrigation purposes a salt content of 300 mg/l is permitted, which is taken as salt wedge. At higher sea level, the wedge of saltwater will penetrate further inland into the rivers and streams accordingly the rainfall and the hydraulic conditions determined by the tidal effect of the ocean. Large part of the Maratakka river, which forms at present a significant fresh water resource for irrigating the rice fields for Wageningen state farm, may become saline. Moreover the salt wedge will intrude into part of the Coronie swamp through the Koffimakka creek and into the Maratakka swamp located between the Maratakka

river and Nickerie river. The ongoing development of rice fields, expansion and reclamation for new fields along the Maratakka river, the Nickerie river and in the north of Koffimakka creek, will be seriously affected. The intrusion of the salt limit to further upstream will have vulnerability consequences for the following :

- withdrawal of freshwater for irrigation purposes since the salt wedge will be found further land inwards than observed at present
- the availability of fresh groundwater for potable purposes, due to additional intrusion of salt into the aquifers
- freshwater availability due to the salt intrusion into the swamps through creeks and small streams
- the natural (mangrove) ecosystems due to high water table and/or high salt concentration
- the breeding, feeding and nursing areas of the coast which is home for hundreds of kinds of birds and other animals
- the coastal soil, which may degrade due to the increased salinity.

3.6 Sea level rise

Elevation of the mean sea level will have the following impacts. The infrastructure of agricultural lands, as for instance the drainage facilities will be affected the most. A higher water level in the rivers, due to the higher sea level, will force the boundary between salt and fresh water to move in the upstream direction. In this way, locations for water intake for irrigation purposes should be replaced, which in turn will require an entire rehabilitation of the irrigation infrastructure. Part of this problem has been solved for the MCP (Multi-Purpose Corantijn-canal project) area, by constructing a ±66 km long irrigation canal, beginning from upstream of the Corantijn river at Wakay and ending in the Nanni creek at the irrigation distribution works north of the Nanni swamp. However, under conditions of one meter SLR and unchanged rainfall amount, the intake location at Wakay will also adversely be influenced. The salinity at the location where currently the salt content is exceeded once in 5 years by the 300 mg Cl/l concentration, will be exceeded more frequently.

Saltwater intrusion was also taken into consideration when the location of the Wageningen polder, the largest rice-producing farm, was created. As mentioned, this polder totally depends on fresh water from the Nickerie River and the Maratakka River. According to reports published by WLA, the salt limit may shift upstream very close to the present intake of the Wageningen polder. A method to stop or to push back the saltwater wedge was included in the Stondansie project, involving the construction of a freshwater reservoir upstream the Nickerie river at the Stondansie falls to regulate the river (figure 1).

Infrastructure for the drainage is based on elements of the river regime, other than that for irrigation. For a better understanding it should be mentioned that the majority of the drainage is based on gravity flow. This means that the amount of water to be drained depends mainly on the value of the hydraulic gradient, which

is defined as the difference between the water level in the drainage canal and in the river. The difference between the two water levels is the greatest at low tide and so are the drainage capacities.

Due to the higher water levels in the river, especially that part of the river which is affected by the tidal regime of the ocean, the hydraulic gradient will decrease and also the period of time, when the river water level is lower than the drainage canal water level. As a result, excess water will remain in the fields because of declination of the capacity of the drainage outlet. This will accumulate surplus water in areas very vulnerable to flooding. Under these circumstances additional pumping facilities will be required for performing the drainage at satisfactory levels, which means additional investments.

4 District Coronie

4.1 Surface water resource

A fourth freshwater source in the north-west of Suriname is the Coronie swamp, located entirely within the territory of this district and is the under the present conditions the main water resource of the district. See for the description of the swamp technical report, part one. This swamp borders in the north by the east-west road and in the east, south and west by rivers. These rivers poorly drain the swamp and are under influence of the tide. In general, throughout the year the swamp feeds the rivers, except during the very dry periods when the rivers are feeding the swamp. The interaction between the swamp and the rivers are not well studied yet.

Large parts of this swamp dry up during the dry seasons and is favourable for being converted into cultivation lands, in particularly for rice cultivation. At present large parts, about 7,000 ha, of the issued concessions within the swamp are being cultivated. For cultivation purposes irrigation water will be withdrawn from the swamp and drainage water will be drained through drainage canals into the Atlantic Ocean or may be recycled.

Fresh water from the swamp is conducted to nature conservation areas, located at the north of the cultivated rice areas in the districts Nickerie and Coronie. For more detail description regarding the nature conservation areas, see technical report for ecology. For conservation purposes and maintaining the ecosystems of the area, which is the nursery, breeding and feeding location for many of birds and species, fresh water is needed. It is therefore being restricted to drain water originating from the agricultural lands into this protected area or using this area as a transit area to drain into the Ocean.

As mentioned for the protected area fresh water is needed to maintain the equilibrium necessary for the (ecological) system to function. In the past, prior to the establishment of the east - west road, a gradual transition of the eco-system could be observed. After the establishment of the mentioned road this transition is impeded. Alteration of the system took place. For rehabilitation purposes of the ecological equilibrium within the northern part of the coastal zone culverts have been placed. However, unplanned ongoing development, in particular rice culture, does not match these intentions. In this regard studies have been initiated whereby a water distribution plan is taken as one of the highest priority. It should be noted that the water resources of the Coronie swamp are still unstudied.

4.2 Groundwater resources and potable water supply

The potential of the resources for potable water here is unknown. The amount of ground water is sensitive to salt intrusion because of the short distance to the ocean. Serious problems are ascertained as shortage of potable water, salinization of aquifers, etc. Currently about 3,000 m3/day water is withdrawn from groundwater for potable purposes. In many parts of the district rainwater is being used as potable water. Surface waters in the districts within and in the surroundings of rice fields are polluted by the used chemicals, such as herbicides and pesticides and is not suitable for potable purposes.

The population growth is negligible in this district and the use of potable water seems not to increase strong.

4.3 Development trend

As mentioned expansion of rice fields within the swamp is taking place, coming up from north to south. The northern border of the swamp with the rice fields is formed by earthen dams. Due to expansion of rice fields part of the swamp is converted into agricultural land, which means that the reservoir capacity is decreasing and so do the water resources. A natural flow of fresh water toward the north is impeded and degradation of the ecosystems is accelerated further. Excessive rainfall often results in dam breaks causing flooding of rice fields. Establishment of new rice fields increases also pollution of the freshwater resources, which on its turn causes harm to the environment.

The Coronie swamp is for its large part undisturbed, notwithstanding the fact that the northern part is already issued for concession for rice cultivation. A 7,000 ha reclamation of land for new rice fields in the swamp is going on and it is expected that this soon will be followed by others concessionaires.

All these developments will exert an additional pressure on the water resources of the swamp and through this on the rivers. The rivers will drain less water from

the swamp and a further intrusion of the salt wedge into the rivers Coppename and Nickerie will be observed.

4.4 Sea level rise

Addition a rise of 1m sea level will have the following impacts:

- Intrusion of the salt water wedges further upstream the river. At present the saltwater wedge in the Coppename River is located at km 73. This limit will shift upstream towards the junction with the Wayambo river, which about 20 km upstream of the current salt limit.
- Accumulation of heaven water in the swamp. This is a serious danger in terms of flooding of the rice areas and other mixed cultures in the vicinity.
- Under conditions of high rate withdrawal of fresh water for irrigation purposes from the swamp, saline water may penetrate into the swamp through small creeks and streams connecting the swamp and the rivers respectively.

5 District Saramacca

5.1 Surface water resources

District Saramacca can be divided into two parts. The northern part borders with the Atlantic Ocean in the north and the Saramacca River in the south. The southern part, including mainly the catchment area of the Coesewijne River and the Coesewijne swamp, is bordered in the north by the Saramacca river and in the south by the Para district.

Tidal waters surround the northern part of the Saramacca district, except in the east, where it borders with district Wanica. In this part of the Saramacca district main economical activities are related to agriculture, in particular rice culture. Water for irrigation purposes are withdrawn from the local swamps and are strongly depended upon the rainfall, so the expansion of rice areas will exhaust the existing water resources. However, notwithstanding these conditions, expansions of rice fields are still continuing on small scale.

It is considered that at SLR of 1m about 80% of the area will be inundated permanently by the sea, so do the freshwater resources. A long term planning for this area is limited, except provisions to establish protected areas. For more detail see technical report "Ecology". The northern part is proposed as protected area. In this regard the above mentioned concerning the need for supply of fresh water to the estuarine zone (see Coronie swamp) is also valid for this part of the Saramacca district.

The southern part of district Saramacca has in contrary with the northern part for the time being enough water resources and potential land for expansion of rice areas. Only a small part of the many concessions issued in this area for rice

culture is currently cultivated. The rice cultivation and land reclamation is concentrated near the mouth of the rivers Saramacca and Coesewijne. For irrigation purposes water is withdrawn from the local swamps, the Coesewijne River and the Coesewijne swamp. Water of the Saramacca River at this location is saline. A water balance study for the Coesewijne swamp has been initiated but not continued. Exhausting of water resources of this region is totally depended upon the expansion of the rice areas and developments in other sectors of socio-economy.

Except the already issued concessions, plans have been developed to develop a mixed agricultural project further upstream the river, whereby possibilities for aquaculture, rice culture, horticulture, etc. will be studied and exploited.

5.2 Groundwater resources and potable water supply

The northern part of the district is less to very less populate. For potable water heaven water are used.
In the southern part the capital of the district, Groningen, is located. Here for potable purposes ground water is used. About 6,000 m^3/day is withdrawn from the groundwater resources in this area. In other small settlements, also located along the river rainwater is use for potable purposes.

5.3 Sea level rise

A SLR of 1m may have various impacts on the ongoing development in the concerned area, i.e.:
- salt intrusion as a result of higher water levels and tides
- flooding as a result of higher water levels in the estuary
- inundation of lands as a result of back water, caused by rainfall in the upper part of the catchment
- damage to infrastructure for the irrigation and drainage facilities. In cases of inundation or flooding infrastructure should be rehabilitated

The above mentioned possible consequences of the SLR and the ongoing development related to the water resources, will result in degradation, exhaustion and, depletion of the water resources in the long term.

6 District Wanica

6.1 Surface water resources

In district Wanica mostly horticulture and mixed agriculture are experienced. Only some recent rice fields are observed. Both, horticulture and mixed agriculture are less water consuming land-use activities. In the rainy season excess water is needed to be drained away and in the dry season on the other hand, irrigation water is needed. For irrigation purposes fresh water is withdrawn from local

small swamps and wells. Moreover heaven water is also used for these purposes and even tap water.

Developments in the north, mainly horticulture and mixed agriculture, have reached close to the shore of the Atlantic Ocean and is still going on. Water resources are not a limiting factor for the further development of these sectors in this district.

6.2 Groundwater resources and potable water supply

The district Wanica is the second well-populated district in Suriname, after Paramaribo, and its population is still increasing, above the other districts, as a result of migration from the districts. Potable water is withdrawn from the ground water, whereby totally about 30,000 m3/day is withdrawn from these resources. Increasing population in the district increases the potable water use and mining of ground water. As a consequence some of the wells located in the coastal zone in the north became saline and have to be closed down. Possibly in the future, following the present development trend of the mentioned sectors and the population increase, potable water need to be conveyed (transported) over long distances, as the local groundwater depletes.

6.3 Sea level rise

If the sea level rises with 1m the salinization process will be accelerated. North part of the district will be inundated and brackish to salt water will penetrate further land inward. The small fresh water swamps in the north will become saline ponds and ground waters in the area will also become saline. Under these circumstances transport of fresh water from south (where fresh water is more abundant) to north for potable purposes will become indispensable. In other words, water resources of this district are very vulnerable to sea level rise.

Other impacts of the sea level rise concern the infrastructure - socio-economical activities and settlements - and increase of the erosion process at the shoreline. These impacts have also as a consequence whether large investments in water transportation will be necessary or not under the circumstances of 1m sea level rise. In case of retreat water transportation for potable purposes will not be necessary.

A possibility for development under the conditions of 1m sea level rise is brackish aquaculture.

7 District Paramaribo

7.1 Surface water resources

District Paramaribo, the most populated district of Suriname and is above all the capital of country, has extensive and valuable infrastructures such as roads, harbors, buildings, settlements, as well as important socio-economical developments, etc. In this district agricultural activities requiring intensive use of water as in the above mentioned districts are less developed or even not practiced. Watercourses are mostly used for navigation, like the Suriname River and the Saramacca canal.

7.2 Groundwater resources and potable water supply

Due to the concentration of the majority nation inhabitants in this district, which is about 50% of the total, use of fresh water for potable purposes is the most developed compared with the other water uses. For potable purposes, about 50,000 m^3/day are being used in Paramaribo surroundings and about 30,000 m^3/day is withdrawn from local ground water resources Additionally water withdrawn from groundwater resources in the district Wanica and Para is transported to this area. Ground water is also used in small industries. The use of potable water depends upon the climatological conditions. Moreover variation in availability of water resources depends not only on the use of it but also on the climatological and other circumstances.

As the population increases the use of potable water will also increase. Increase of population here is expected to be the largest in Suriname. Under the present situation limitation in withdrawal of local ground water for potable purposes is experienced, as the water in the aquifers becomes saline. Intrusion of brackish water is taking place under the present situation. This is a consequence of mining of ground water . If the development is continuing under the present circumstances, the intrusion of salt water will be located far into the coastal zone.

A rehabilitation project concerning potable water in Paramaribo and surroundings is being implemented at present. Increase of transport of water withdrawn from groundwater from district Para, where groundwater resources are large and its withdrawal is in favor conditions is included.

7.3 Sea level rise

A sea level rise will bring limited impact on the existing water resources in the district. Large impact will be exerted on the infrastructure and other economical activities. As has been mentioned before, drainage in the coastal region mostly takes place by means of gravity, which is tidal depended. High drainage requirements in Paramaribo result in the need for establishing of pumping

stations at different locations, which pumps the excess drainage water into the Suriname River. At a sea level rise of one-meter drainage by means of gravity will be almost impossible and establishing of additional pumping stations will be a must, which means extra investments.

Harbors and other structures along the banks of the river will be inundated at a sea level rise of 1m. Depending upon the policy of the government these structures will be shift or transfer to another suitable location or adapted to the new water levels in the river. According to the ongoing development, among others the construction of a bridge over the Suriname River, it is quite clear that structures, as harbors will be adapted under the future conditions of 1m sea level rise. Other structures, such as the navigation lock at Saramacca Doorsteek, should also be adapted to the new conditions.

1 meter sea level rise means to navigation in the first place that larger ships can enter the harbor, under the condition that no additional sedimentation will take place in the river.

8 District Commewijne

8.1 Surface water resources

Geographically district Commewijne is comparable with the district Saramacca. The area is flat and low elevated and a meandering main river –Commewijne River– is flowing towards a greater main river, see technical report part one. The whole area of this district can be divided into two parts:

- The northern part (right bank Commewijne River). This is the area between the Atlantic Ocean in the north and the Commewijne River in the south. In the east this area is bordered by the district Marowijne.
- The southern part (left bank Commewijne River). This is the area south of the Commewijne River up to the southern border of the district and is in the west bordered by the Suriname River and at the east by the Marowijne district.

8.1.1 Northern part of the district

In the northern part of the district except some creeks or small streams many small saline to freshwater swamps are to be observed, which can be utilized for water-based developments in the district. At present development of aquaculture is being practiced. At present two farms are in operation; the first one (Comfish) is a semi intensive production farm, using large areas for its farm and the second one (Comas) is an intensive production farm, using relative small scale of areas. Both farms are making intensive use of the (local) water resources, both brackish water from the river as well as fresh water from the swamps. Favourable conditions for further expansion of these farms are present. This makes that other stakeholders are willing to invest in this flourishing sector. The amount of brackish water is present in huge amount while the fresh water could be a limiting

factor if unplanned expansion takes place. Fresh water shortage may take place, especially during the dry season. The fresh water resources in these areas are mainly dependent on the rainfall. Focusing back on the rainfall trends given in technical report one, one can draw a conclusion that the rainfall trend is rather unstable and depends on the location in the coastal zone. Increase of global temperature will have serious effects on the fresh water resources in the coastal area, through increasing effect of evapotranspiration and possible declination in rainfall amount.

8.1.2 Southern part of the district.

Most of the activities in the Commewijne district take place in the southern part, which area is far larger than that of the north. The population is mostly concentrated along the bank of the Commewijne River and the east-west road. A small number is to be found along bank of the Suriname River. The water-based activities is concentrated further upstream the Commewijne river and in the vicinity of the freshwater swamp in the south. Potable water here is gained from the groundwater resources.

The southern surface fresh water resources of the Commewijne River and the Ricanau swamp in the district are not fully exploited yet. Their potential offers possibilities to develop water-based (related) activities, as agriculture, aquaculture, and other type of mixed cultures.

8.2 Development trend

In general district Commewijne has a bright future. The establishment of a bridge over the Suriname River connecting Paramaribo, the capital of the country, with district Commewijne will have positive impact on the future development of the district. Large-scale urbanization may occur and new developments might be initiated and carried out. Abandoned areas in this district will be converted in other land-use type, Mixed agriculture will increase, horticulture will establish and changes concerning the development of other land-use areas as mentioned in the technical report of the socio-economy will take place. To what extent these changes will take place, depend among other factors mainly on the policy of the government. At present there is no such a planning to regulate the development of this district. Under these conditions it is very difficult to conjecture the development.

On the other hand is it clear that the apart from mentioned development will results in population increase above the natural population growth in this district. The population growth will mainly concentrate in coastal zone of the district, close to the rivers Suriname and Commewijne. The northern part of the district will remain less populated in relation to the southern part.

Water resources in this district will play important role in all developments. In the northern part of the district, large possibilities are present for practicing aquaculture, whilst, in the southern part large possibilities are present for practicing agriculture related activities.

The water resources, as well as in the north as in the south of the district is very sensitive to changes in the climatological conditions, especially in of the north, where the water resources are entirely depended on the amount of rainfall. Although the water resources in the south also depend upon the rainfall, the river flow in the dry seasons is mainly determined by the groundwater flow, amount of which is determined by the geological characteristics. Following the rainfall trend of station Alliance one can conclude that the amount of rainfall does not show a negative development. It has been shown in general, that the trend of rainfall in the southern direction, so land inward, is positive, which means increase of rainfall in time as one moves in the southern direction. The maximum rainfall is observed in the vicinity of Tafelberg.

Vulnerability of the water resources mainly depends on the method of exploitation of water resources. Uncontrolled use of water resources may result in depletion and exhaustion of these resources in long term. In addition to this the increase of population and water-based activities in the area will further accelerate this development.

8.3 Ground water resources and potable water supply

The use of groundwater resources is restricted only for potable purposes, mainly for New Amsterdam, the capital of the district and some other settlements among others Alliance. The use of groundwater resources is at present low and will increase as the population increases, which is expected to grow as a result of establishment of the bridge connection between the districts Paramaribo and Commewijne. Totally about 15,000 m^3/day of water is withdrawn from the ground water resources

8.4 Sea level rise

Parts of the district, apart from the inter tidal area, are under the present hydro-meteorological and hydraulic conditions being flooded yearly, as a result of high spring waters and bad maintenance of sluices and other structures. Flooding also occurs as a result of river dyke failures along the Suriname and Commewijne rivers. This illustrates the sensitivity of the area for high waters.

According to the Stakeholders of the district, as the sea level rises, larger areas are flooded and inundated. Saltwater penetration due to the inundation causes harm and loss to the local economy. Inundation and flooding of areas causes also salinization of the areas, which is unfavourable for plant to growth. These

areas have to be rehabilitated again and again after every flooding or inundation by leaching process, artificially or naturally by rainfall.

As the sea level rises up to 1m, the fresh water resources in the north will vanish and salt and/or brackish water pans will occur. Saltwater will penetrate deeper into the river Commewijne and may reach Cassewinica creek, which finds its origin in the Ricanau swamp. This means that large part of the swamp will be saline to a certain extent. The salinization of these water resources will affect to the development of the district extremely negative.

Salt wedge penetration into the Cottica river will not intrude very much further into the river, because of the topography. In case the amount of rainfall decreases or water withdrawal from the river increases, the salt wedge will shift deeper into the river. For so far the development concerned there are no water withdrawal activities planned or projected in the future in this area.

1m sea level rise will cause also backwater in the river. The location of the backwater will lie far upstream the Commewijne river, as the catchment area is low and mainly flat. Due to stagnation of excess water the total area of Ricanau swamp will increase and will cause inundation to the neighbor located farms and other human settlements.

Sea level rise will therefore impede the drainage of excess surface waters from the district into the rivers. The structures as part of the irrigation and drainage system should be replaced or transferred to other suitable and safety locations or have to be abandoned permanently. In all of these cases large investments have to be made, in order to maintain functioning of the present irrigation and drainage systems, or establishment of new irrigation and drainage systems.

9 District Marowijne

According to the topography of the district only a relatively small strip in the coastal area, bordering the Atlantic Ocean, is relatively low and flat. Larger part of the district is hilly and is beyond the flooding zones defined above. In this small strip all three types of swamp are to be observed, however in a very small extent. It is therefore that water related activities are less developed in the district Marowijne, also because of the infertility of the soil. In this area only one village is to be found, village Galibi. Extensive land-use types are shifting cultivation, mixed agriculture and bauxite mining. No further activities are to be observed in this area, except nature preservation in the" Galibi nature reserve" (See the technical report "Ecology" for further information). Furthermore a rehabilitation project for Albina, the local capital of district Marowijne has currently been executed, involving the defense of the left bank of the river Marowijne to stop further erosion. Other developments on long term are not known, except

rehabilitation of Albina, to which high priority is given. Hence, it appears, that population increase is to be expect in Albina in the future.

For potable purposes groundwater is used, resources of which the capacity is not determined yet. Totally about 1,000 m^3/day is withdrawn from the ground water resources. At present there is no indication of fresh water shortage in Albina.

Surface water resources are determined by the Cottica river and its tributaries and the Marowijne river. However, both water resources, surface as well as ground water resources are less developed in this district. Except the bauxite industry, small amount of fresh water is used for agricultural purposes. Most of the cultivation are rain-fed, as for example the shifting cultivation. As rainfall varies shifting cultivation may suffer seriously.

At a 1m sea level rise only a small strip as mentioned above will be inundated. Practically only the existing estuarine eco-system and the village Galibi will be affected. The capital Albina will not be inundated. During the Stakeholders meeting this has also been suggested. Another impact of the 1m sea level rise is the intrusion of salt wedge in the Marowijne River. Due to less development along this river and water related activities, the salt wedge intrusion will have a small effect on the economical activities in the district.

10 District Para

A small part of District Para is included in the study area. This district is located in comparison with the already mentioned districts on high grounds, where a sea level rise of 1m will have limited impact on the socio-economical activities. Indeed in district Para the Suriname River, Saramacca River and the Tibiti River are flowing. Therefore the effect of sea level rise will be conducted into the district through the rivers and the water level will rise partly as result of backwater effect due to sea level rise, which means that this water level will fluctuate according to the tide of the ocean. Inter tidal area may occur in the northwest part of the district at river Tibiti. In this case the salt wedge may be observed. Currently in case of high spring water and low freshwater discharge, salt wedge may reach the district only through the Suriname River.

In this district the largest bauxite industry of Suriname - Paranam - is situated. Water resources are mainly used in this industry. Totally about 35,000 m^3/s of water is withdrawn from ground water.

11 District Sipaliwini

Only a small part of this district, bordering at rivers Tibiti and Coppename may fall in the zone of inter tidal area, Z10 zone and Z100 zone respectively. Their areas are less then 0.3% of the total area of district Sipaliwini. The effect of sea level rise will be conducted also into this district through the rivers and the water level will rise partly as result of backwater effect due to sea level rise. This means that the water level will fluctuate according to the tide of the ocean. Also here, inter tidal area may occur in the north part of the district along the river, namely Tibiti and Coppename river.

In the concerned area there is only little population and there are no large-scale activities going on, which means no pressure are being exerted on the present water resources. This situation will be unchanged in the coming future. There are no plans or projects for this area in the future.

For potable purposes mainly surface water and rainwater is used. Ground water resources in this region are very limited. Totally about 6,000 m^3/day of water is withdrawn from groundwater for potable purposes.

Salt wedge might reach the north border of district Sipaliwini through the river Coppename, which will be the worst case. This will happen only under conditions of dry climate and high water spring in combination with an 1m sea level rise.

List of Tables

List of figures

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APPENDIX

Fig: 1

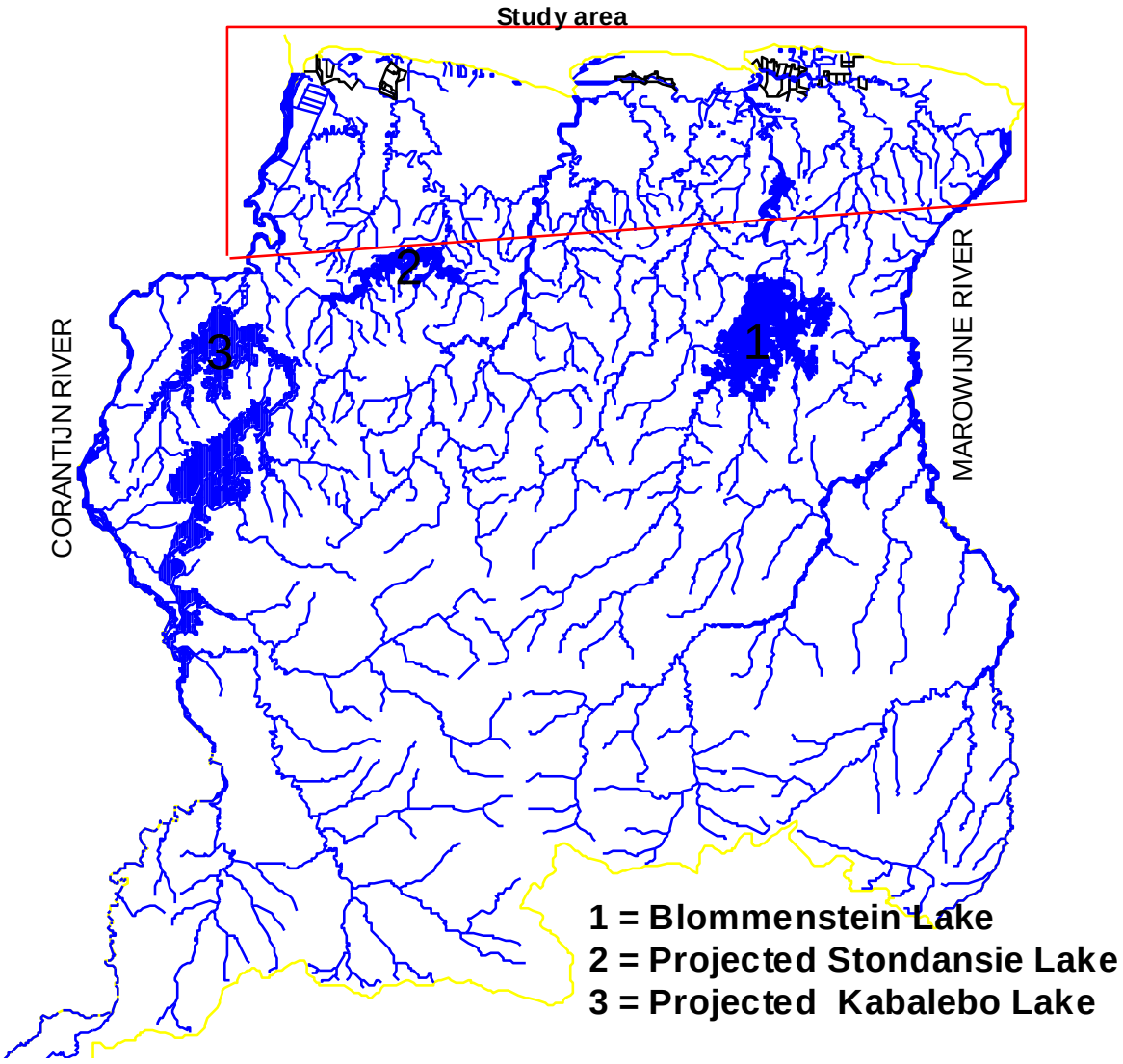

Study area
CORANTIJN RIVER
MAROWIJNE RIVER
1
2
3
1 = Blommenstein Lake
2 = Projected Stondansie Lake
3 = Projected Kabalebo Lake

fig: 2

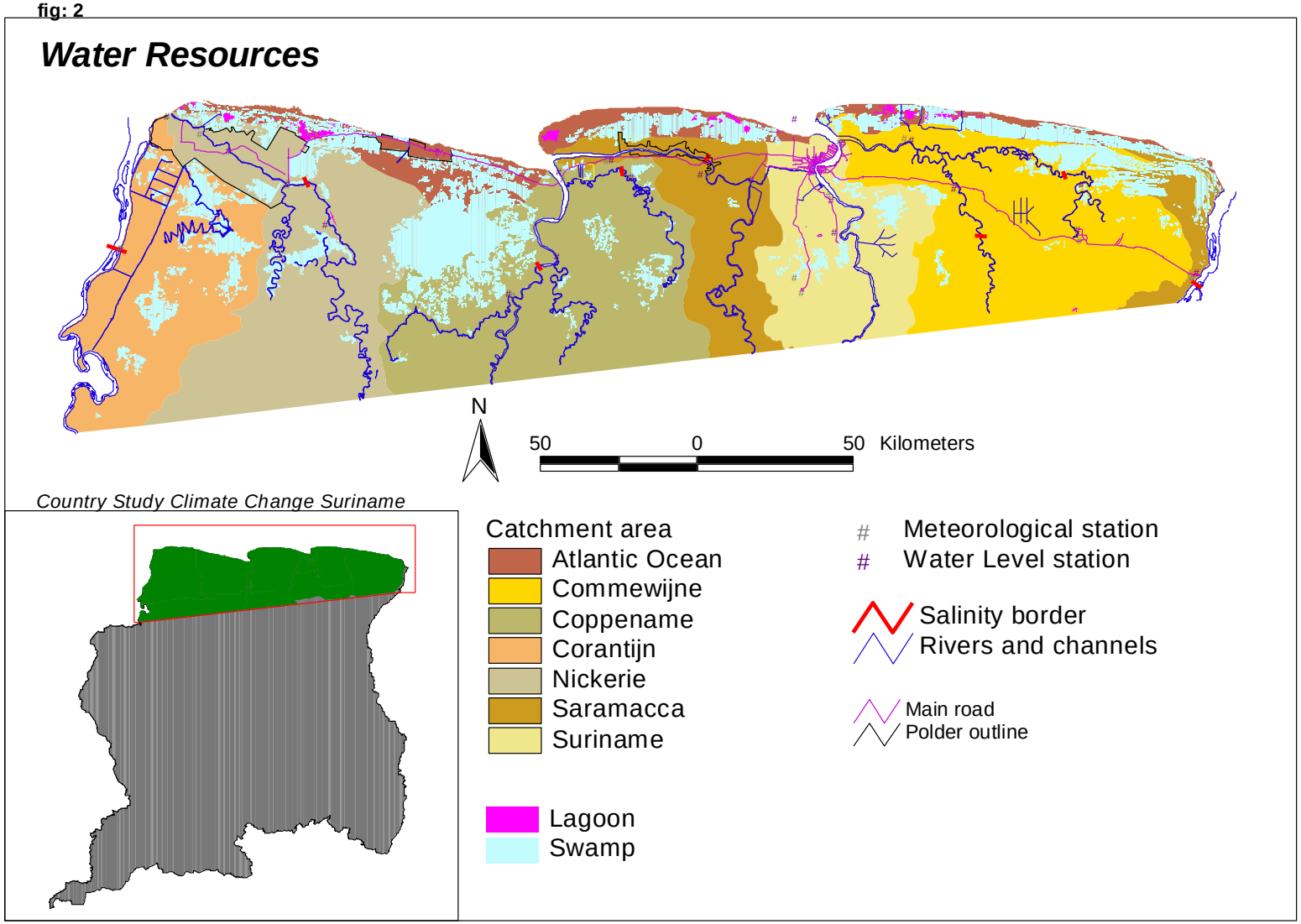
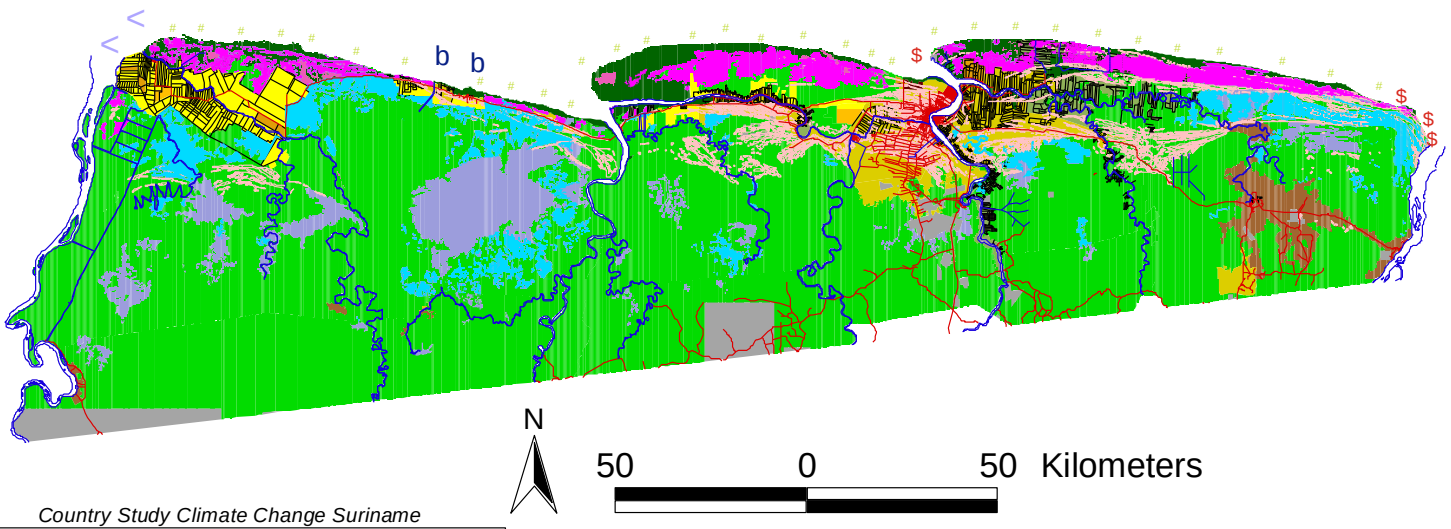
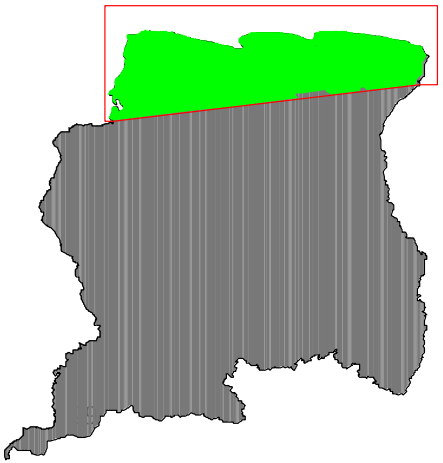

Water Resources
N
50
0
50 Kilometers
Country Study Climate Change Suriname
Catchment area
Atlantic Ocean
Commewijne
Coppename
Corantijn
Nickerie
Saramacca
Suriname
Lagoon
Swamp
Meteorological station
Water Level station
Salinity border
Rivers and channels
Main road
Polder outline

Fig: 3

Summary of Coastal Characteristics



Country Study Climate Change Suriname



Land cover / Land use
- Rice
- Banana Plantation
- Horticulture
- Mixed Agriculture
- Shifting Cultivation
- Lagoon/Pond
- Open swamp
- Mangroves
- Swamp Forest
- Mining
- Urban Area
- Grassland
- Abandoned Plantation
- Fresh water zwamp
- Saline to brackish swamp

- b Secondery sea dyke.
- < Sea dyke
- $ Sand beaches
- # Mud bank

- Ridge
- Polders
- Rivers and Channels
- Roads

Fig: 4

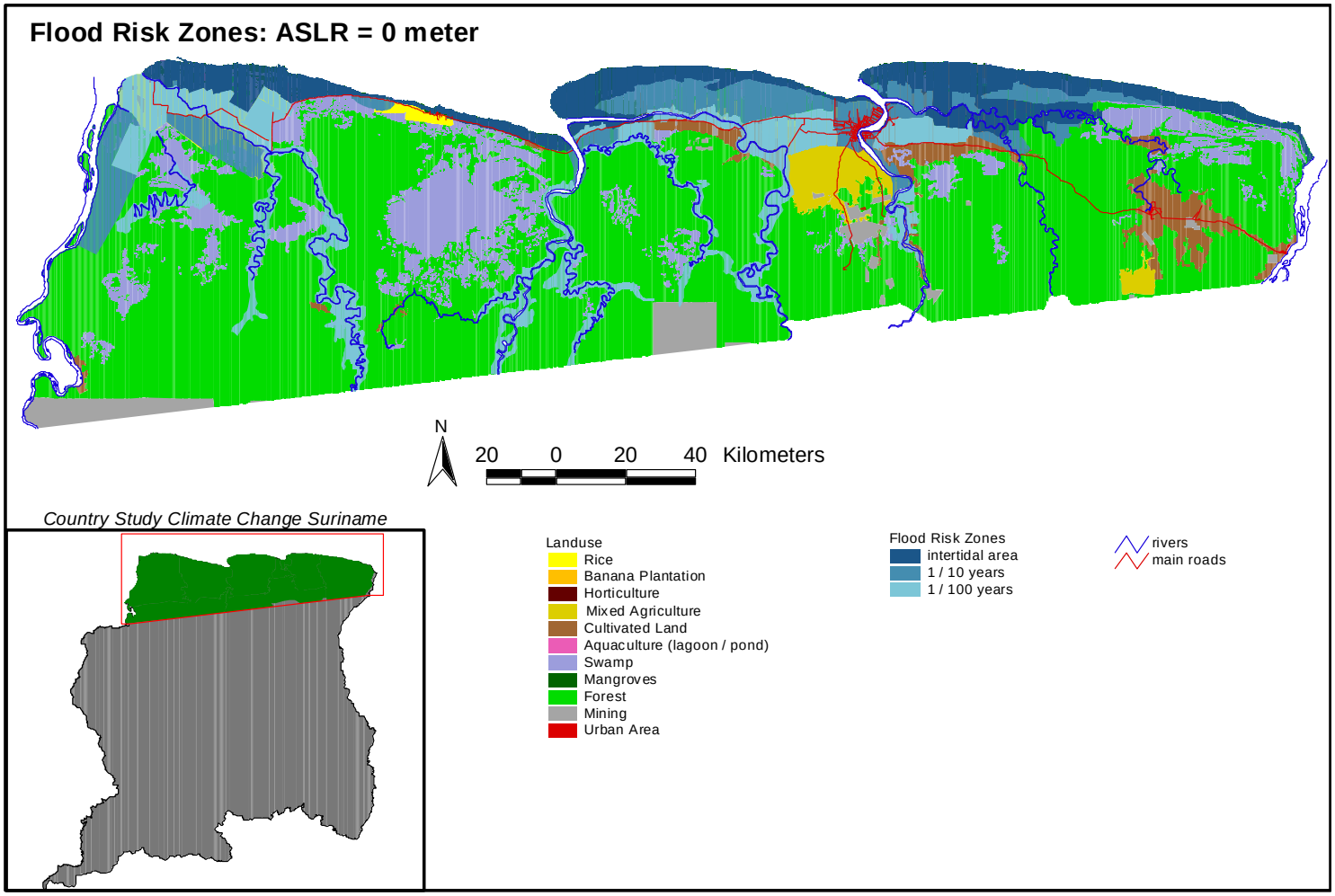
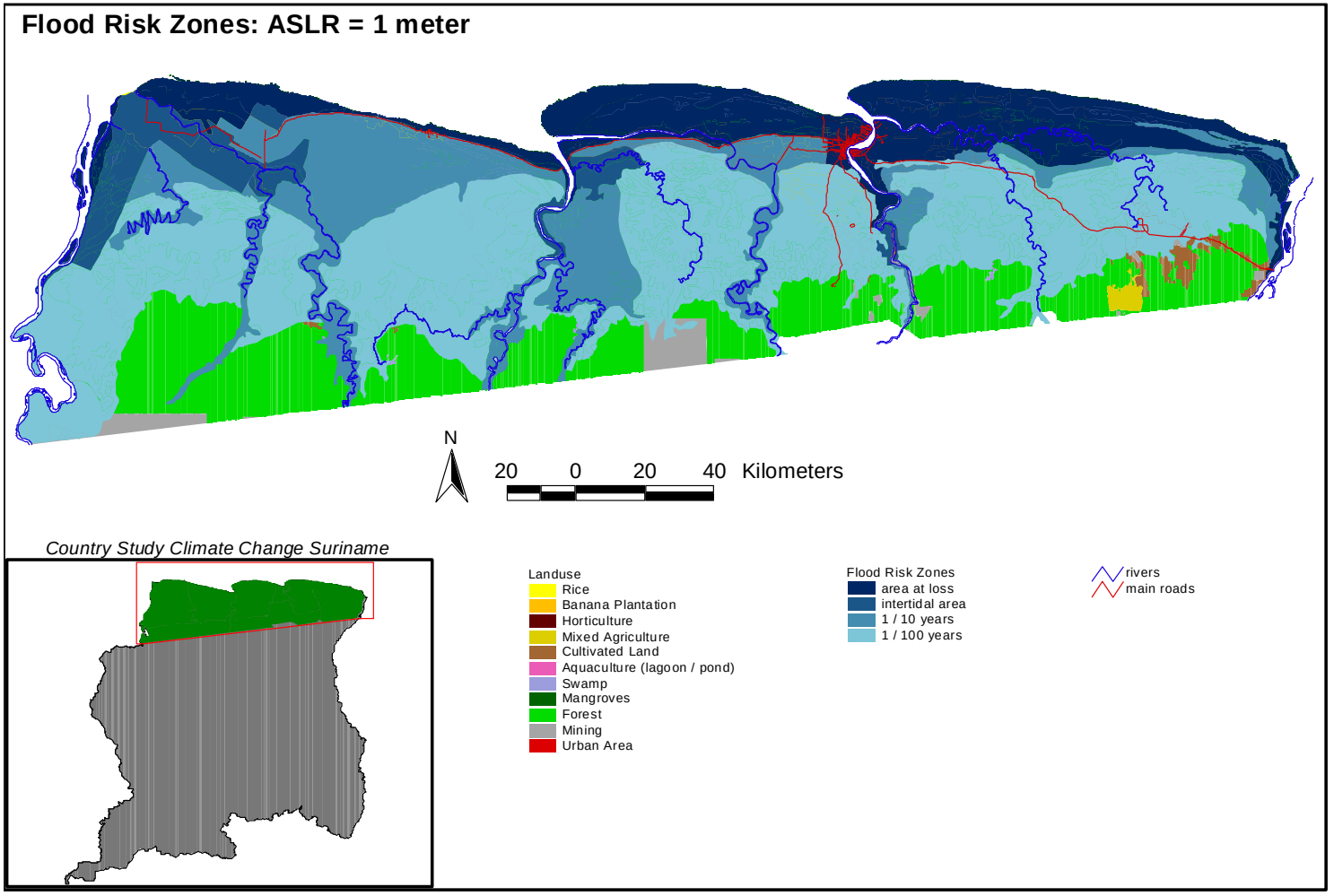

Flood Risk Zones: ASLR = 0 meter
N
20 0 20 40 Kilometers
Country Study Climate Change Suriname
Landuse
Rice
Banana Plantation
Horticulture
Mixed Agriculture
Cultivated Land
Aquaculture (lagoon / pond)
Swamp
Mangroves
Forest
Mining
Urban Area
Flood Risk Zones
intertidal area
1 / 10 years
1 / 100 years
rivers
main roads

Fig: 5


Flood Risk Zones: ASLR = 1 meter
N
20 0 20 40 Kilometers
Country Study Climate Change Suriname
Landuse
Rice
Banana Plantation
Horticulture
Mixed Agriculture
Cultivated Land
Aquaculture (lagoon / pond)
Swamp
Mangroves
Forest
Mining
Urban Area
Flood Risk Zones
area at loss
intertidal area
1 / 10 years
1 / 100 years
rivers
main roads